WIRED

MAR-APR 2023

PEDRO PASCAL

THE STAR OF THE LAST OF US – AND EVERYONE'S ANTI-HERO

DON'T FEAR AI – IT'S GOING TO SAVE HUMAN CREATIVITY

GUYANA, EXXON, AND THE TICKING CARBON TIME-BOMB

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AI BIAS AND REAL-WORLD HARM

Abeba Birhane is a cognitive scientist exposing rogue datasets that are rife with prejudice and sexism, yet still exert influence over the algorithms that run our lives

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The last two

Northern white rhinos are on the brink of extinction—but an Italian lab may be able to bring them back via southern surrogates

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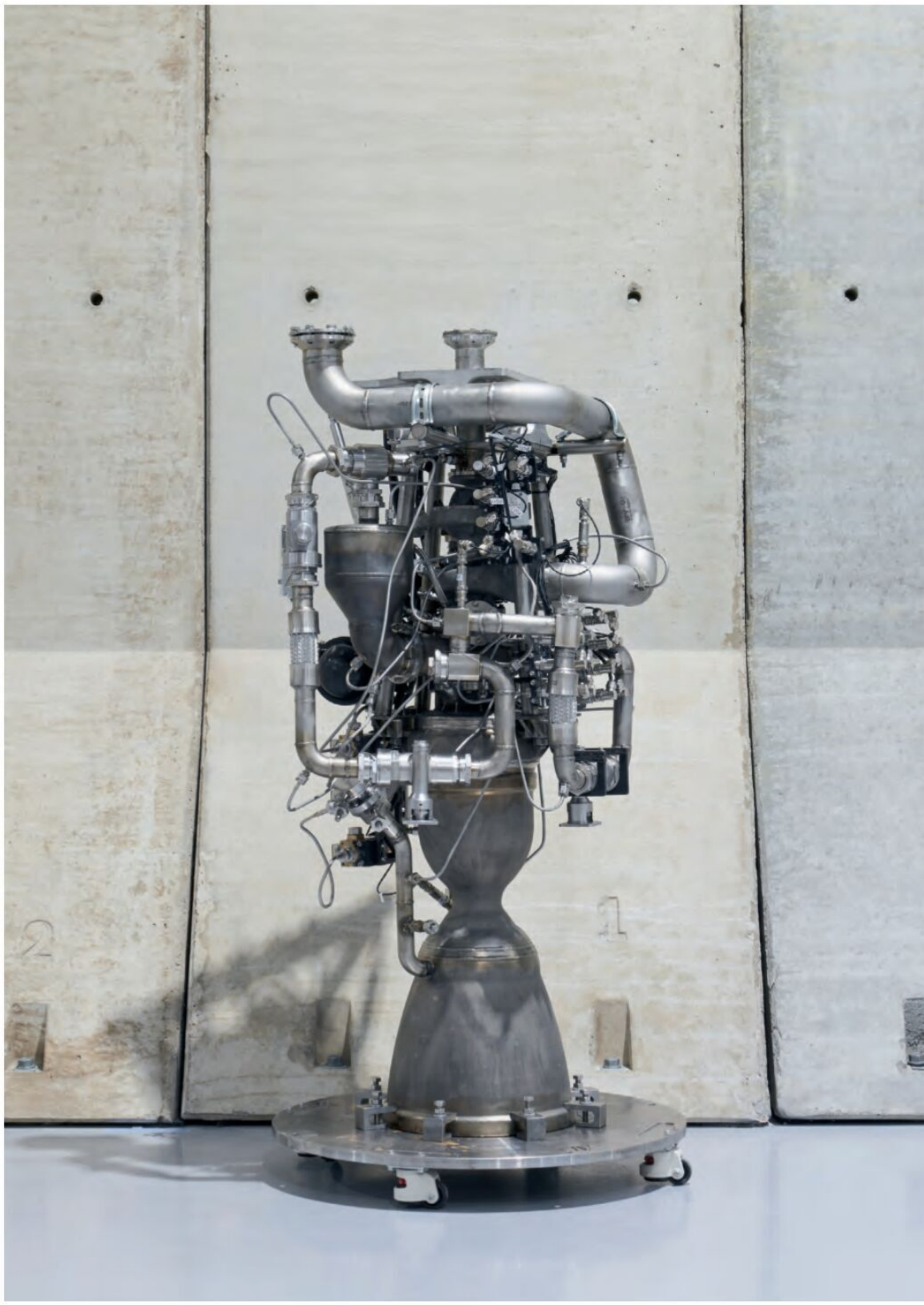
Since 2015, Exxon has discovered 11 billion barrels of oil off the coast of Guyana. One lawyer is going up against the petroleum behemoth

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Crypto keeper

How iPod's mastermind Tony Fadell made Ledger's new hardware wallet—a tiny vault for digital cash—flashy and fun

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Very small wasps

Earth is teeming with unknown species, and they're dying out faster than ever—so how should we be cataloging them?



In Skyrora's factory in Cumbernauld, Lanarkshire, workers assemble the stages of rockets that will be launched from one of the UK's new spaceports.

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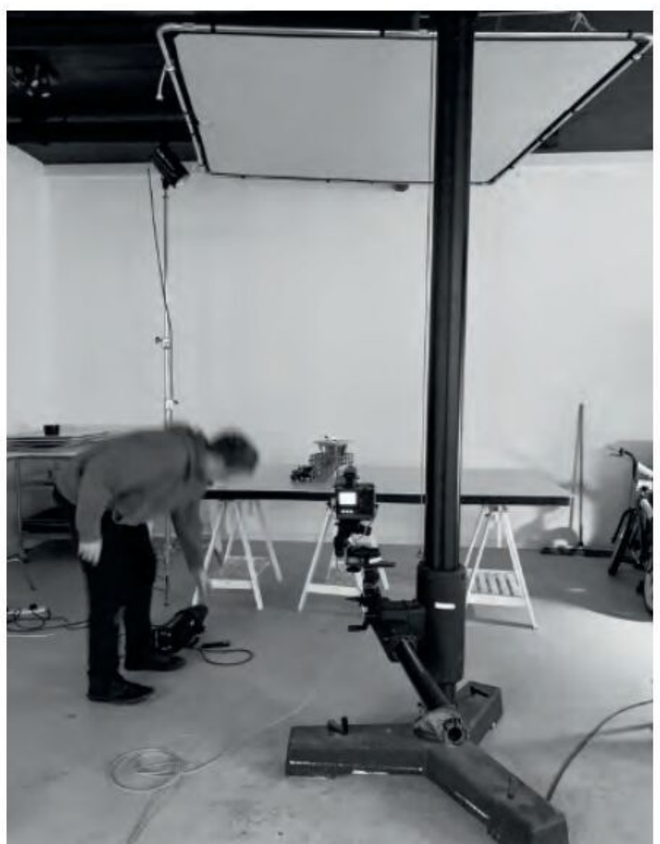
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CHARACTER ACTOR

He's billed as the complicated face of sci-fi, but Pedro Pascal—a specialist in gritty characters full of contradictions—is actually a delight: "We were going for moody lighting," says Los Angeles-based photographer Peter Yang, of our cover star. "Pedro really played well to the different setups, going from funny to dramatic in a blink of an eye. He was cracking us all up."

Creating WIRED



THE BIG IDEA

Mitch Payne had to channel *Gulliver's Travels* for this issue's Gear photoshoot, using ultra-realistic scale models to make tiny gadgets look massive: "WIRED always lets me get hands-on with cool new kit, but adding some shameless adult playtime while mixing and matching diggers and fire engines to tech products? Next-level fun."



HEMAL JHAVERI

Jhaveri meets Pedro Pascal—star of *The Last of Us*, *The Mandalorian*, and, apparently, the nicest man in showbiz. "He's most engaged when we talk about family and politics," she says. "He cares so much. He's also uncomfortable caring so much."



ANTONIA JUHASZ

The author and activist reports on the fight to stop an oil giant exploiting a huge oilfield off the coast of Guyana. "The scale of it lands Guyana on the list of top 'carbon bombs'—fossil fuel projects capable of releasing more than a gigaton of CO_2," she says.



GRACE BROWNE

Browne profiles Abeba Birhane, a cognitive scientist working to root out harmful bias from datasets powering AI algorithms. "Birhane reckons shifting attitudes will drive change," she says. "Big Tech firms respond to outrage more than regulation."

PHOTOGRAPHY: PETER YANG; MITCH PAYNE. ILLUSTRATION: MATTHEW GREEN



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Remember the excitement about the return of the "Roaring Twenties"? As financial markets, juiced by quantitative easing, roared out of the global Covid pandemic, many future-gazers predicted the return of a gilded age similar to that of a century before, one that heralded a period of exceptional growth and prosperity.

There is a tendency to think of the 1920s culturally: Cities from Chicago to Berlin experienced a surge of creativity in theater and music, while social progress saw women achieving equal voting rights in both the US and UK.

What is sometimes forgotten is that it was also a period of immense technological advancement—radio became a mass medium (CBS, NBC, and the BBC were all founded in the 1920s), and there were rapid developments in automobiles, aviation, and electrical appliances for the home. New gadgets like vacuum cleaners, spin dryers, and electric razors ushered in an era of mass consumption.

We were promised something similar when the world emerged from the macroeconomic trauma of the pandemic. The development of vaccines demonstrated humankind's ability to innovate, technology companies had prospered on the back of broad shifts in the economy, and it appeared that our capacity to collaborate in addressing the most pressing challenges presaged a bright(ish) future.

Fast forward to the beginning of 2023, and tightened monetary policy means that most growth forecasts for the US, EU, and UK are grim. Even China is significantly lower than before the pandemic. But national data doesn't tell the whole story—while economies might be struggling broadly, this isn't consistent geographically. Many cities are experiencing a version of the Roaring Twenties.

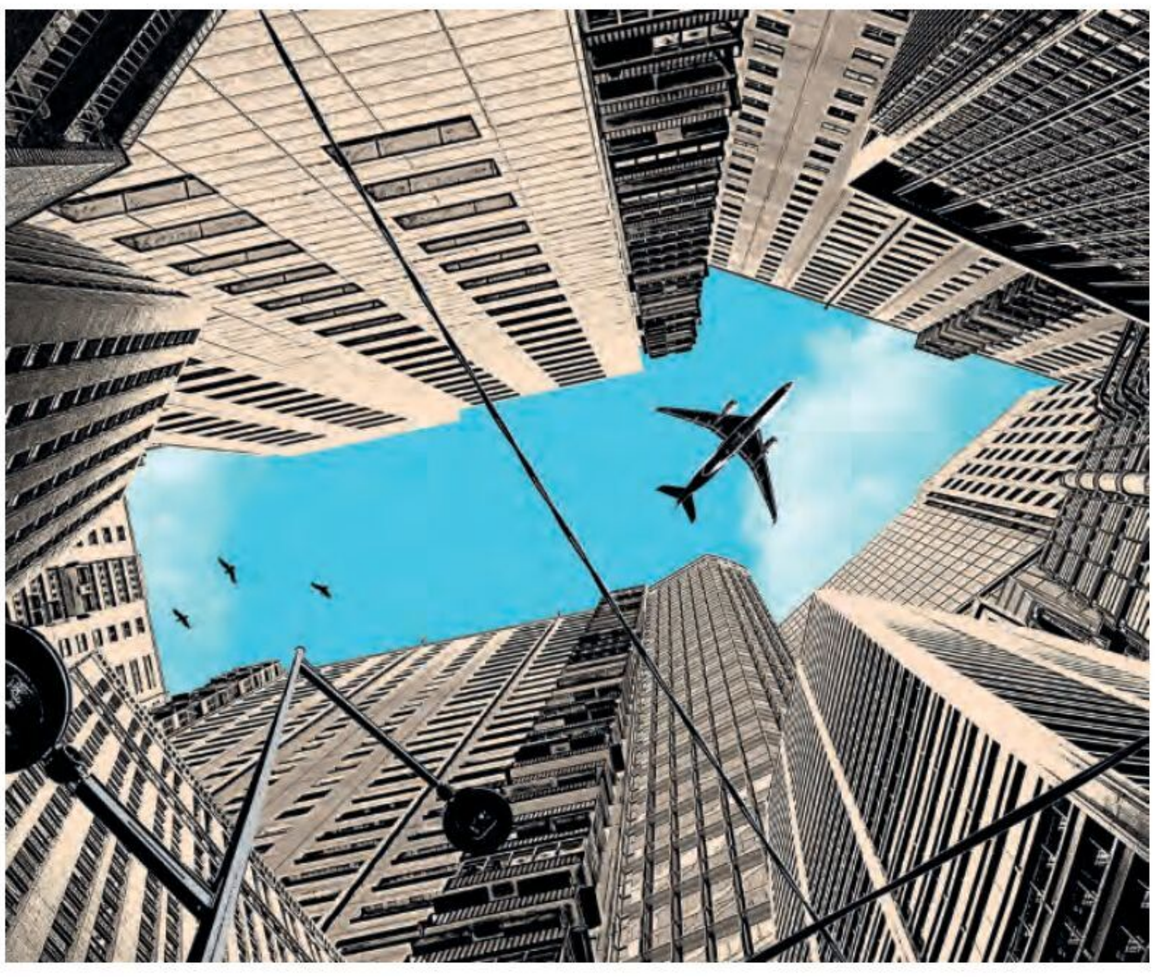
According to the World Bank, 80 percent of GDP is generated in cities. A recent study by The McKinsey Global Institute shows that these hubs of economic activity cover just 0.9 percent of the world's land mass, yet they contain 27 per cent of the global population, roughly two billion people. From Shenzhen to Bangalore and Dallas, these urban centers were responsible for half of the increase in global output over the first two decades of the century. The World Bank estimates that 70 percent of the global population will live in cities by 2040: The most populous will be in South Asia and Africa.

Beyond being centers for economic activity and innovation, cities have significant roles to play in addressing many of the challenges we face, from inequality to climate change. The rise of the city state has been a phenomenon for the past decade, with local leaders sometimes at odds with their counterparts at a national level. Often they are able to act with greater urgency and levels of accountability because of their granular understanding of challenges—for instance, the member mayors of the C40 Cities Climate Leadership Group collaborating on climate change. Cities will continue to be the hubs of innovation around mobility, construction, and finance that will be critical to tackling climate change.

The wisdom during the pandemic was that the era of the city state was over. Now they are our best hope for increased productivity and innovation.

ILLUSTRATION: GREGORI SAAVEDRA

Radical innovation is needed to tackle our biggest challenges. City states are leading the way





Greg Williams
Deputy global editorial director

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Edited by
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THE

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Keeper Zachary Mutai and **Najin, one of only two northern white rhinos left in the world. Najin lives in Kenya's Ol Pejeta Conservancy.**

LAST

TWO

Cesare Galli unscrews the lid of a liquid nitrogen canister and pulls out a sample of something invaluable: a pair of embryos from the northern white rhinoceros. The species is functionally extinct, ravaged by poaching and habitat loss. Since 2018, just two northern white rhinos remain—both female, and both unable to bear young.

Galli is the founder of Avantea, a biotech company based in northern Italy that is hoping to bring the Northern white rhinoceros back from the brink. "When you eliminate a species from the ecosystem, you risk throwing everything off-balance," he says. "Rhinos are maintaining the balance. The danger to their survival comes exclusively from us. It is our duty to make amends."

So far, Galli's lab has created fourteen embryos, using artificial insemination to combine sperm from two deceased male rhinos with eggs from Najin and Fatu, the two remaining females. Najin and Fatu are mother and daughter—descended from Sudan, the last male northern white rhino.

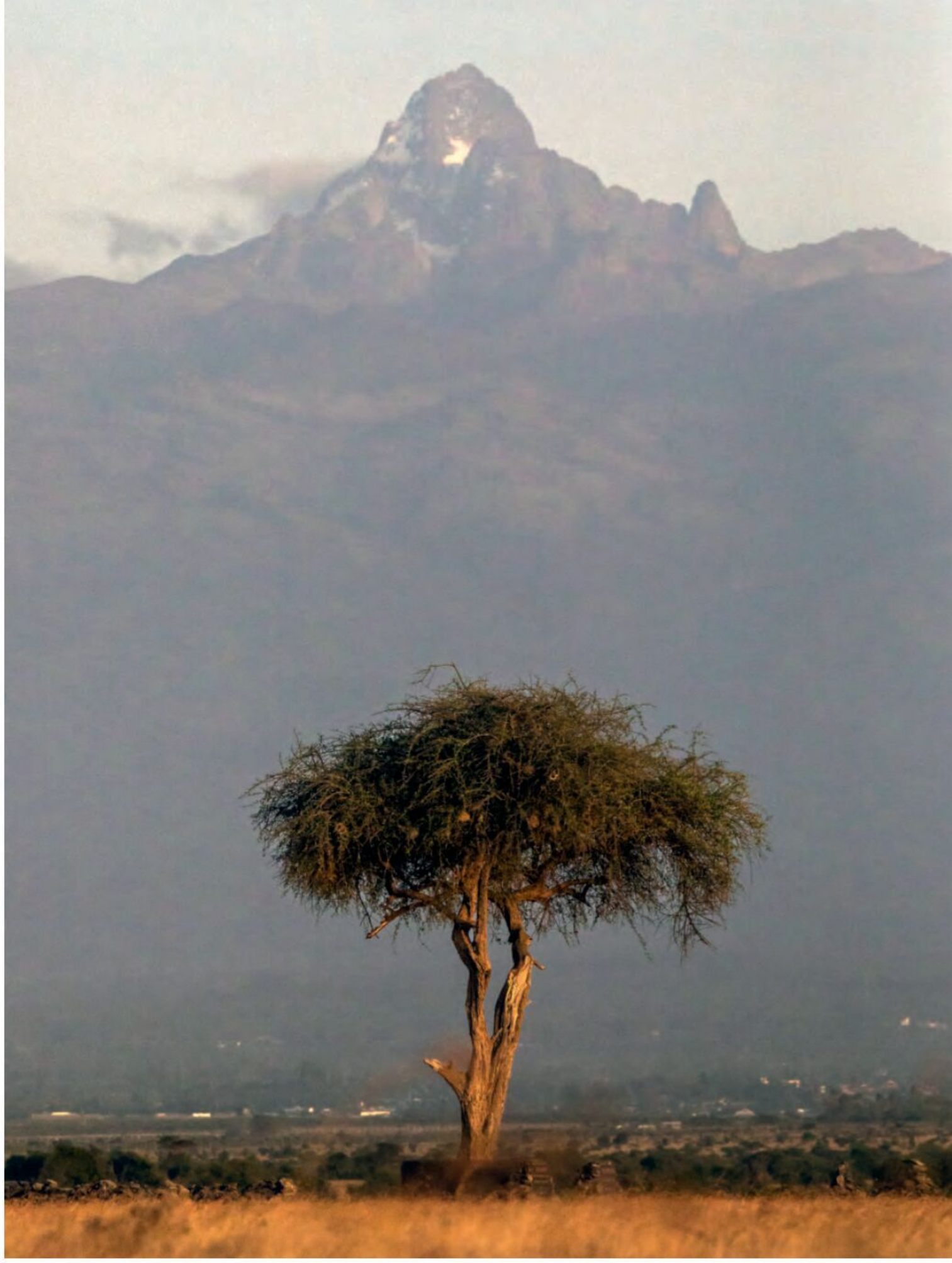
In 2009, the trio—and a male called Suni—were moved from a zoo in the Czech Republic (where the females and Suni were born) to the Ol Pejeta Conservancy in Kenya, in a last-ditch effort to save the species. By that point, it had been nine years since the last northern white rhino was born, but it was hoped that a return to a more natural habitat might encourage Suni and the females to successfully mate.

The plan failed. Suni died of natural causes in 2014, and Sudan followed four years later. By then, vets had already confirmed that neither Najin or Fatu would be able to have offspring in the natural manner: Fatu because of pathological degeneration in her womb, Najin because years of living in a cage in the Czech Republic had weakened her hind legs to the extent that she would no longer have been able to bear a male's weight (if there had been any males left to bear). "Their reproductive capacity is severely diminished," says Stephen Ngulu, head veterinarian at Ol Pejeta, of the two remaining females. "But they're in pretty good health."

In 2015, a group of 20 scientists from five continents began to draw up a rescue plan for the northern white rhino.



Ol Pejeta's main veterinarian Stephen Ngulu (wearing gloves) checks 32-year-old Najin.



Memorial stones commemorate Ol Pejeta rhinos lost to poachers; 16 markers surround the tree.



A scientist at Avantea's lab prepares a mature oocyte cell so it can be injected with sperm.

Galli was invited to join the project—a consortium called BioRescue—because of decades of experience in the world of elite horse reproduction. Avantea's lab, near the Italian town of Cremona, was the first to artificially impregnate a mare after directly introducing a sperm cell into the cytoplasm of an egg cell.

After that, Galli began working on rhino embryos: perfecting the method with the less-endangered Sumatran and southern white rhinos, before creating the fourteen northern white rhino embryos using eggs harvested from Najin and Fatu—they're the size of a human fist and have to be carefully removed while the animal is under heavy sedation. The embryos have been kept in cold storage at -196°C since 2019. Since Najin and Fatu cannot carry those embryos themselves, southern white rhinos will be used as surrogates instead.

At least, that's the idea: to start with, the scientists will hone their methods with southern white rhino embryos, working up to the northern white rhino, which could take up to five years, says Galli—although he admits he's been saying that for a while.

"It's an expensive project," says Richard Vigne, who was, until recently, Ol Pejeta's CEO. "Many people are saying it's not worth it, saving a single species while thousands of others are dying out. We disagree." Vigne says the northern white rhino project has already brought tremendous global attention to animal extinction issues—it remains to be seen whether it can bring this particular species back from the edge of oblivion.

"If we create four embryos per year, that makes sixteen in just four years," says Galli. "If we reach a 50 per cent success rate, as we already have with horses, we would have eight new animals. This won't be enough to repopulate the whole of Kenya, but it would be a good start."

PHOTOGRAPHY: MATJAŽ KRIVIC

BOŠTJAN VIDEMŠEK *(@bosthi) and* **MAJA PRIJATELJ VIDEMŠEK** *(@majaprija) are climate journalists.*



For the good of kids, web design has a new code

The internet is accessed by all ages—and a new code aims to ensure its youngest visitors are protected. Designers and platforms need to be aware.

One in five people who access the internet are children, but the web wasn't designed for them. The UK's Children's code aims to fix this—helping to make the internet a safer place for young people. This means enshrining the highest level of children's data security in law—and ensuring greater privacy protections for everyone else in the process.

Developers who design games, online sites or applications that might be accessed by children—even if this is not their target market—now have to conform to the Children's code. As a developer, this means building new practices into how you work, such as determining the ages of those who access your sites, switching settings to "high privacy" as the default, and not sharing children's data.

And there are other settings to take into account: Did you know that geolocation services should now be switched off as standard? Or were you aware that so-called "nudge techniques" shouldn't be used to entice children to share unnecessary personal data?

The code took effect on September 2, 2020, and all digital companies must now be compliant. Failure to follow the code could result in enforcement action.

"At first we were unsure of the scope of the code and if it would apply to our business," says Sarah Norford-Jones, cofounder of secure messaging platform YEO Messaging. "Now we're looking at our privacy notices and other terms and conditions that children might need to understand. The Children's code has made us think differently about a whole group of users."

The UK's Children's code is a pioneering piece of regulation, overseen by the Information Commissioner's Office, that other countries would likely adopt. Developers of apps or websites with users in the UK can get ahead of this global movement by embodying today the principles that make the internet a safer, more rewarding place for people of all ages.

To learn more about the Children's code, go to *ico.org.uk/cc-design guidance* or call the helpline on 0303 123 1113.

The Children's code aims to make using the internet safer for kids.

ILLUSTRATION: VALENTIN TKACH



PHOTOGRAPHY: LAURENCE MCMAHON

Abeba Birhane wants to end the algorithmic biases that can cause real-world harms.

AI BIAS IS A REAL-WORLD PROBLEM

Dirty datasets are harming women and marginalized groups. Big Tech needs to get serious about data audits

t's been said algorithms are "opinions embedded in code". Few understand that better than Abeba Birhane. During her PhD in cognitive science at University College Dublin, Birhane—who was born and raised in Ethiopia, and moved to Ireland to study—realized no one was asking what goes into the huge datasets often used to train artificial intelligence systems.

These datasets are often scraped from the web for cost-effectiveness and ease. But that means AI can inherit all the biases of the data that feeds it. It mirrors society, with all the ugliness baked in.

Ignoring this risks real-world harm. AI has been accused of underestimating the health needs of Black patients, for instance, and making it harder for people of color to get mortgages.

Often, one only has to scratch the surface to find problems. In 2020, Birhane and colleague Vinay Prabhu audited two popular datasets. "80 Million Tiny Images" is an MIT set that's cited in hundreds of academic papers and has been used for more than a decade to teach machine learning systems to recognize people and objects. It was full of offensive labels—racist slurs for images of Black people, for example. In the other dataset, ImageNet, they found pornographic content, including upskirt images of women, which did not require the individuals' explicit consent because they were scraped from the internet. Two days after the pair published their study, the MIT team apologized and took down the Tiny Images dataset.

These problems come from the top: machine learning research lacks the diversity of the communities it purports to help, and Big Tech firms now hold enormous power over real-world events.

Birhane and others have branded this "digital colonialism"—arguing that Big Tech's power now rivals the old empires. Its harms will not be evenly spread, she says: as technology is exported to the Global South, it carries Western norms and philosophies with it. It's sold as a way of helping underdeveloped nations, but it's often imposed on people without consultation, pushing them further to the margins. "Nobody in Silicon Valley stays up worrying about the unbanked Black women in rural Timbuktu," says Birhane, who now combines lecturing with a senior fellowship at the Mozilla Foundation.

Birhane reckons shifting public attitudes will be the most effective driver of change: Big Tech firms respond to outrage more than regulation. But she doesn't want to live in a cloud of bile: as a Black woman doing critical work, she has faced pushback from day one. "I don't know if I can live my life fighting," she says.

For every problematic dataset that's revealed, another lies waiting: In 2021, Birhane and colleagues wrote about LAION-400M. Containing more than 400 million images, it returned explicit pornography when prompted with even mildly feminine words such as "mummy". The paper triggered outrage, but the dataset still exists, and has swelled to more than five billion images; it recently won an award.

While creating datasets for AI is fairly simple, auditing them is time-consuming and expensive. There is no incentive to make a clean dataset—only a profitable one. So, the work falls on the shoulders of researchers like Birhane, for whom it takes a toll—having to spend hours looking at racist imagery. "It's really depressing," she says. "It really can be traumatizing."

Ideally, change would be driven by the vast resources of Big Tech, not by independent researchers. But corporations are unlikely to self-reform. "I want, in an ideal world, a civilized system where corporations will take accountability and responsibility and make sure that the systems they're putting out are as accurate and as fair and just for everybody," Birhane says. "But that feels like it's asking too much."

GRACE BROWNE *(@gracefbrowne) is a staff writer at* WIRED.

THE COOL SCIENCE OF STOOLS

Extinction threatens all sorts of living creatures, both great and very small. So, scientists are racing to preserve rare gut-bacteria, and it all starts with frozen poo...

In November 2022, Swiss scientists opened an eagerly awaited package from rural Ethiopia. It was full of shit.

For two months, public health researcher Abdifatah Muhummed had been collecting stool samples from children in a remote, pastoralist community in Ethiopia's Somali Region, as part of a global effort to catalog and preserve the diversity of human gut bacteria. He split each sample into four tubes, froze them at -80°C, and shipped two of them to Europe.

Trillions of bacteria, fungi and other microbes live in the digestive tract. Many of them are beneficial to human health—influencing our metabolism and immune system, for example. But their diversity is under threat from industrialization, urbanization and environmental changes. When Muhummed analyzed some of the samples he'd collected—culturing them in petri dishes and adding a dye to make them visible under a microscope—he was astounded to find signs of antibiotic resistance, even in samples taken from children who had never been exposed to modern antibiotics.

That's one of the reasons scientists want to create a global biobank—a Noah's Ark of gut microbes, so to speak—and permanently store samples from around the world, before it's too late. "Of course, it is difficult to concretely say what we are losing," says microbiologist Adrian Egli, who is based in Zurich and is part of the launch team for the Microbiota Vault project.

Stool samples from pastoralists are of particular interest to scientists, because diet affects the human microbiome. "Their lifestyle is totally different from people who live in cities or urban areas," says Muhummed, a doctoral candidate who collected more than 350 samples as part of a collaboration between Jigjiga University, the Swiss Tropical and Public Health Institute, and the University of Basel.

Pastoralists use milk as a staple food, so their diet is rich in fatty acids. Because they are nomadic, pastoralists have until now rarely been surveyed in health studies, moving their flocks of sheep, goats and camels among the few grazing areas left after years of drought in East Africa. And, they have little access to medical care.

As more people move to cities, they adopt new eating habits and are exposed to a different environment. Pastoralists in Ethiopia are also starting to buy more foods such as rice and pasta, according to Muhummed. This could change the composition of their microbiome, and push the specialized bacteria living in their guts to extinction.

In the Microbiota Vault, tens of thousands of stool samples from healthy people all over the world could one day be permanently stored so that the different species of bacteria are not completely lost. They could even be revived and cultured to treat diseases in the distant future.

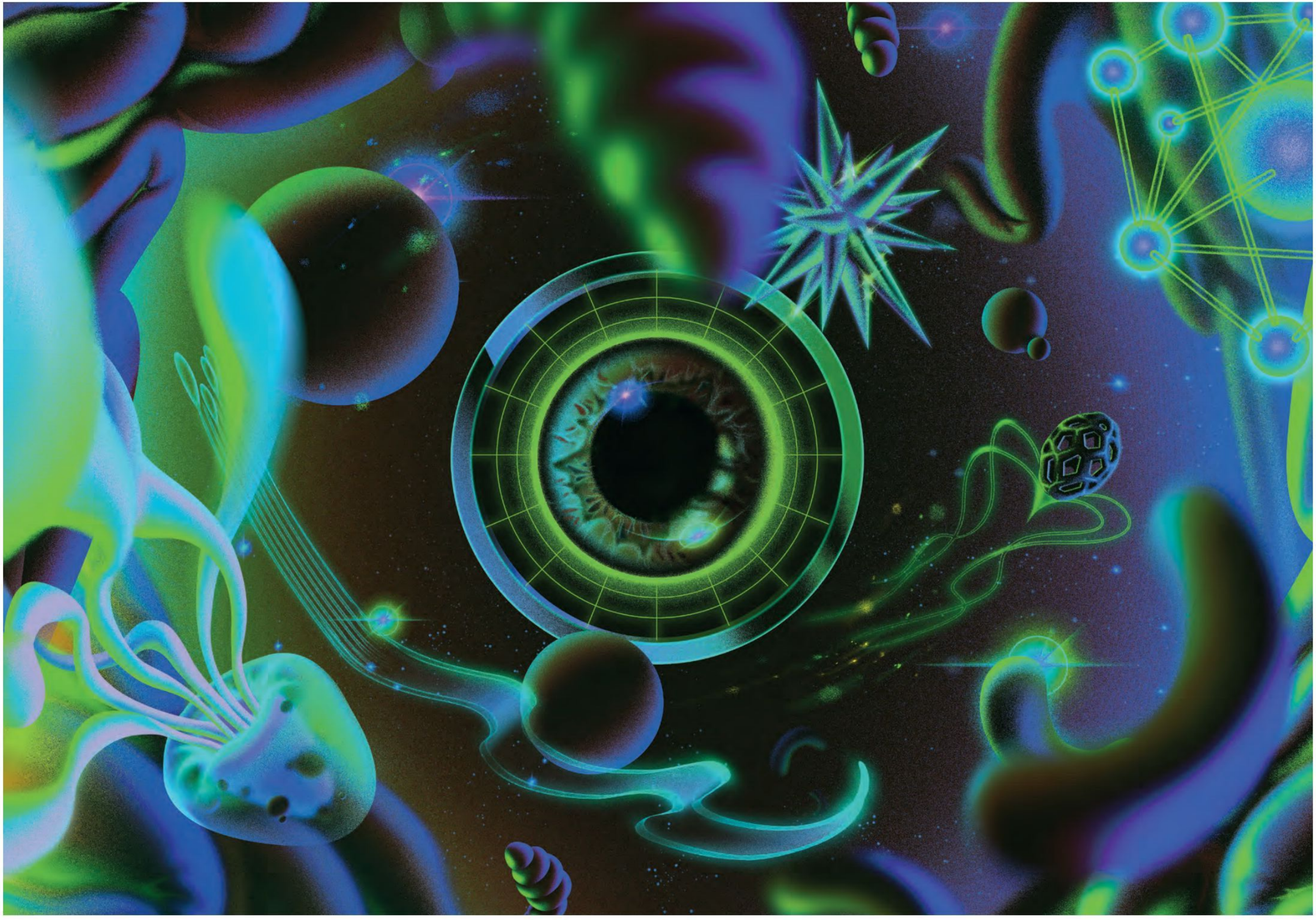
There are already dozens of stool banks and numerous ongoing efforts to sequence human microbiomes by researchers, all of whom may want to keep their samples in the vault. Like Noah's Ark, contributing researchers would divide their samples into two specimens, one for the vault, the other for them to keep locally (suppliers retain ownership of all samples). "It's a give and take, a win-win for both sides. We provide the infrastructure, but we also get access to the sequencing data at some point," says Egli. The Microbiota Vault project team, aims to document and publish sequencing data in a standardized form to facilitate international research.

Where the actual vault, currently just a freezer in Egli's lab at the University of Zurich, will be built is still undecided: It could become part of the Svalbard Global Seed Vault in Norway, or sit in a converted military bunker in the Alps—Switzerland's political stability, good infrastructure, and its links to international agencies such as the World Health Organization in Geneva make it a suitable candidate. The $1 million in funding will cover the pilot phase of the project until 2024.

To realize their vision, Egli and his colleagues need to test which freezing techniques and preservatives keep the bacteria alive long-term. They'll find out when the first batch of samples is thawed and sequenced again after two years. "Then we can say which method best preserves microbial diversity," he says.

SABRINA WEISS *(@SabrinaMWeiss) is a Zurich-based journalist who covers science, health, and the environment.*

ILLUSTRATION: PRINCESS HIDIR



DIGITALIZED DELIVERY HAS ARRIVED

Autonomous, electric, emission-free and on-demand, trucking is about to be turned into a desk job, where 'drivers' remotely monitor their cabs from a workstation

In Selmer, Tennessee, a truck carries parts between a GE factory and a warehouse, navigating roads and loading bays. One thing it's not carrying: a driver.

In November, this electric truck—called the Pod and made by Swedish startup Einride—became the first to negotiate a public road in the US, combining LIDAR, satellite and night-vision cameras to find its way, with help from a remote operator.

Einride's CEO Robert Falck and his cofounder and CMO (and wife) Linnéa Kornehed are proud of that autonomous milestone, but say they're more focused on the power of electric vehicles to make a real difference in the climate crisis.

Freight accounts for eight per cent of global emissions, and two thirds of that comes from trucks. In 2016, the couple decided to do something about it, building on Falck's experience working at Volvo. "We wanted to solve one of our times' biggest challenges," says Kornehed. "People said electric freight will never work, but we knew the technology was there."

Diesel is ten times more energy dense than batteries, providing more fuel for less weight, and right now Einride's trailer trucks can travel a maximum of 650 km on one charge. But as regulators clamp down on emissions, the freight industry will need to change.

Philipp Rose, an electric trucking expert at PwC's Strategy& consultancy, estimates that 70 percent of trucks across the EU, China, and North America will have swapped diesel for cleaner alternatives by 2030, "with discussions to even beyond 50 percent emission cuts by then," he says.

But because of the limited range, Falck believes that only half of road freight transport can currently go electric, with longer and rural routes stuck on diesel, and perhaps later switching to hydrogen or biofuels.

This will change the way companies operate, says Rose. Local distribution hubs will mean trucks don't have to go the whole distance, while shorter, less onerous routes could also address the driver shortage.



Einride's Pod doesn't have a cab for a driver, but a human can still remotely monitor its journey.

Einride wants to rebuild freight as a "transport as a service" industry: it doesn't make the trucks itself, but its Saga software platform provides data-driven coordination for scheduling loads, battery recharging and routing.

Customers such as Oatly and Beyond Meat book exactly what transport they need on the platform, rather than hiring drivers or leasing trucks. "The transport industry hasn't gone through the digitalization phase yet," says Kornehed. "We're talking to customers that are still using pen and paper and fax." Falck draws a comparison with the impact of Uber on the taxi industry: "You need that digital platform to unlock the potential of electric," he says. Autonomous trials like the one in Tennessee have helped Einride secure another $500m in financing, but the start-up's focus remains on lowering emissions.

Removing human drivers from the cab would lower costs, but Falck says that efficiencies such as being able to drive through the night, or timing deliveries so you don't need warehouse space are key. Still, he admits that the Einride Pod will probably always require a remote operator. "It will keep the human in the loop for decision making and interactions," Falck says. When an animal walks in front of the truck, "A human needs to decide to honk the horn." *einride.tech*

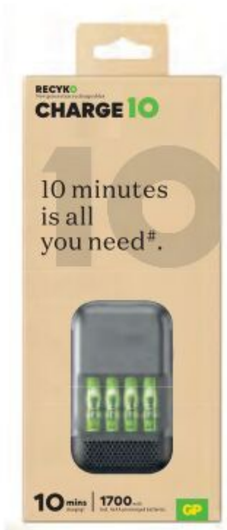
NICOLE KOBIE *(@njkobie) writes about technology, transport, and science.*

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Corals are dying out in unprecedented numbers in the waters around Australia, but there is hope they can be saved from the ravages of a warmer, more acidic ocean. Biologists are working to fast-grow hardier specimens that can be propagated and transplanted by robotic arms

A ROBOT ASSEMBLY LINE FOR CORAL

Taryn Foster believes Australia's dying coral reefs can still be rescued—if she can speed up her efforts to save them. For years, Foster and other biologists have been lending a hand to reefs struggling with rising temperatures and ocean acidity: they've collected coral fragments and cut them into pieces to propagate and grow them in nurseries on land; they've crossbred different species to build in heat-resistance; they've experimented with probiotics as a defense against deadly diseases.

But even transplanting thousands of these healthy and upgraded corals onto damaged reefs will not be enough to save entire ecosystems, Foster says. "We need some way of deploying corals at scale." Sounds like a job for some robots.

In a healthy ocean, individual corals called polyps build their distinctive skeletons by extracting calcium carbonate from seawater. They then fuse with corals of the same genetic makeup to form huge colonies—coral reefs. But as the ocean absorbs more carbon dioxide from the atmosphere, the water becomes more acidic, making it difficult for the polyps to build their skeletons or to keep them from dissolving. Acidification inhibits reef growth, and with global ocean temperatures rising, corals are struggling to survive.

In the Great Barrier Reef, for instance, coral growth has slowed in recent decades, partly because during heat waves, the tiny algae that live inside the coral's tissues and provide them with nutrients, are expelled, causing them to bleach. Bleached corals are not dead, but are more at risk of starvation and disease, and the loss of coral reefs has a devastating impact on the thousands of fish, crabs, and other marine animals that rely on them for shelter and food.

Growing replacement corals in a nursery and manually grafting them onto existing reefs is labor intensive, expensive, and slow. Corals are naturally sluggish growers—they take 3 to 10 years, depending on the species, to build an adult-sized skeleton. With her company, Coral Maker, Foster is trying to accelerate this process. Before her research on coral reefs and climate change, Foster worked in her family's masonry business. Now she is using the family's dry-casting machines to produce limestone shapes that resemble the natural skeletons of corals—the plan is to provide young corals with a suitable foundation from which they can grow faster.

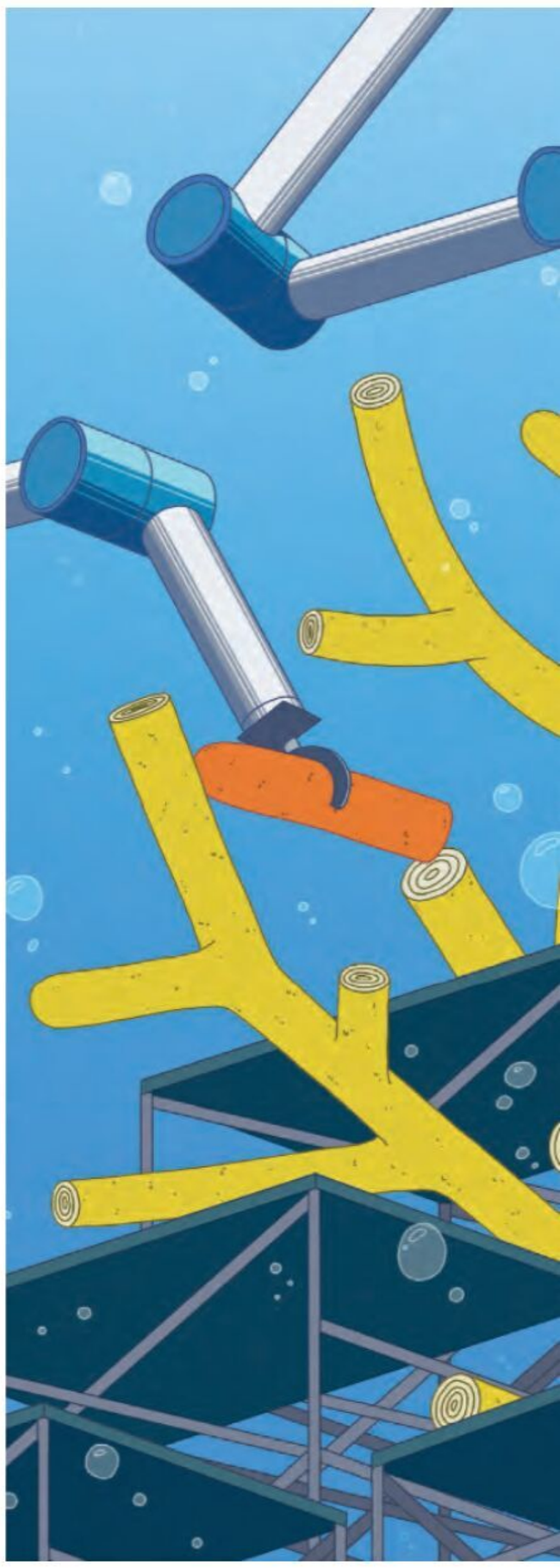
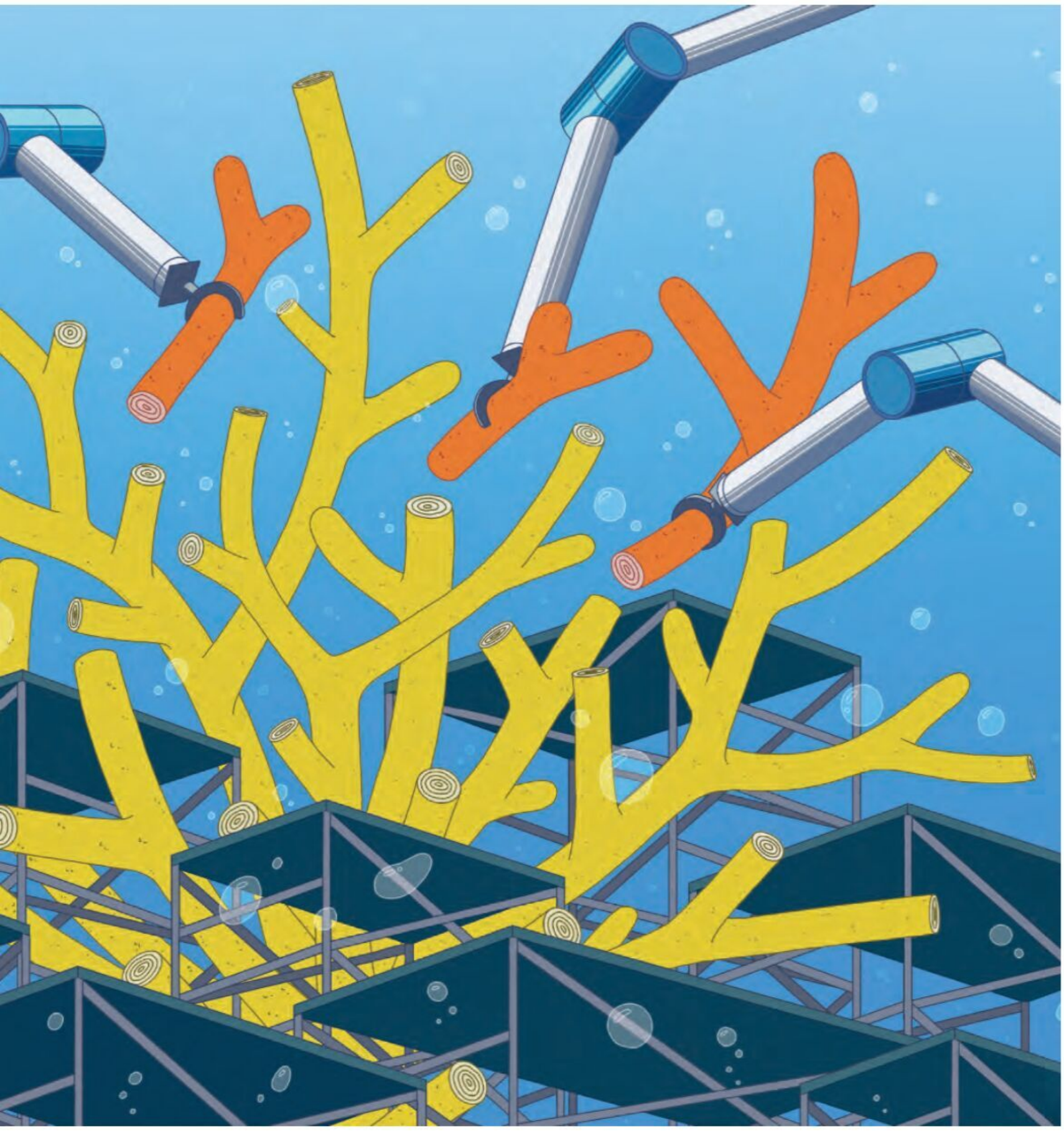


ILLUSTRATION: JAEDOO LEE

The first prototype of the Coral Maker skeleton is dome-shaped and has six plugs where live coral fragments can be placed. The skeleton design takes inspiration from nature: Many species such as brain corals grow in a dome shape, while branching or plate corals grow upward from a solid base. But there are also challenges with dome-shaped skeletons, says Foster. "They're not as easy to manufacture as something with a flat surface, they're not as easy to pack on a pallet, they're not as easy to glue stuff on to." That's why Foster continues to tinker with the design, so that the masonry machinery can soon produce up to 10,000 pieces a day for just a few dollars. The process could then be replicated in other factories.

Once multiple coral fragments with their premade skeletons are planted out on reefs, they could reach their full size within 12 to 18 months. That's considerably faster than they would need without help—provided the location, water, and light conditions are suitable. Corals like it warm, but not too warm; bright, but not too bright; they like water currents that bring in food, but which don't destroy their delicate structures. "They're a bit picky," Foster says.



Foster has been growing a first batch of corals in premade skeletons for over a year on a coral farm near Abrolhos Island in Western Australia, where she lives. The purpose of the first trial was to test how easily divers can transport the limestone skeletons and how the coral fare in an area with good conditions. On December 2, 2022, Foster and her colleagues deployed a second batch of corals on a sandy patch on the underwater farm. This time, the premade skeletons were in the shape of a disc, with a small handle for a human diver or a remotely-controlled vehicle.

Even as the corals happily encase their skeletons, Foster says that the manual tasks on land will have to be automated to produce around 1.7 million corals on 280,000 skeletons per year. She is currently working with researchers at the Autodesk AI Lab in San Francisco to develop and train two types of robotic arms with image sensors: one capable of cutting coral fragments into smaller pieces and gluing them into plugs, and one that can implant those plugs into the limestone skeletons. Once these are up and running on an operational scale, she says, the goal is to have multiple projects on different reefs and coastlines around the world." I think of this as a delivery or scaling mechanism for these other technologies that people are developing, like coral propagation," says Foster. "Just at a much faster rate and on a bigger scale."

SABRINA WEISS *(@SabrinaMWeiss) is a Zurich-based journalist who covers science, health, and the environment.*

HAILING A RIDE INTO EARTH ORBIT

In a factory on the outskirts of Glasgow, aerospace manufacturer Skyrora is building a rocket-based taxi service for satellites

Nine engines, 50,000 liters of fuel, seven tonnes of thrust and a velocity of 8 KM a second are needed to put a rocket into orbit. For Skyrora, a private launch-vehicle provider in Scotland, that's just step one.

Rather than passengers, its payload is satellites. "Satellite data was once predominantly used for government security," says Volodymyr Levykin, the company's founder and CEO. "Now, private companies are trying to have next-level communication and observation."

If the old Space Race was between rival nations, the next is being waged by competing businesses. "Elon Musk has pioneered the private space race with SpaceX," says Levykin. "Silicon Valley [believes] space is tech's new frontier."

Space startups are emerging all over the world. Levykin says most are in the US, with China, India and Europe playing catch-up. The UK government aims to increase its share of the global space market to ten percent by 2030, when the industry may be worth around £400 billion.



It's why Levykin launched Skyrora in 2017. He says Scotland offers a clear trajectory to the North Pole—crucial for a sun-synchronous satellite orbit—as well as easy access to UK spaceports: five of the seven that are planned will be north of Hadrian's Wall. Skyrora designs and builds its rockets in its factory in Cumbernauld, Lanarkshire, deploying them at its test blast area on the outskirts of Edinburgh.

Its flagship rocket, the Skyrora XL, which can carry a 315 kilogram payload, will be ready for launch from the Shetland Islands in 2023. Levykin says clients will likely be intermediary satellite companies that sell their data to businesses. "There's so much information that can be collected from space that can be actioned in real-time across verticals, from farming to insurance. We just arrange the transport."

SpaceX provides a similar service: its satellite rideshare program offers slots on the Falcon 9 for $275,000. The key differentiator for Skyrora, says Levykin, is that it offers dedicated launches. “Space X is more like a bus service: you can only use it with other passengers. We’re like a taxi: we can depart when the customer wants.”

Instead of an average two-year wait for a ride on a Falcon 9, Skyrora’s aim is six months between customer contact and liftoff—but it means the ticket price will likely be three times that of SpaceX. “We’re addressing the niche for customers who don’t want to share their payload with others. It’s for those where time is more critical than money,” says Levykin.

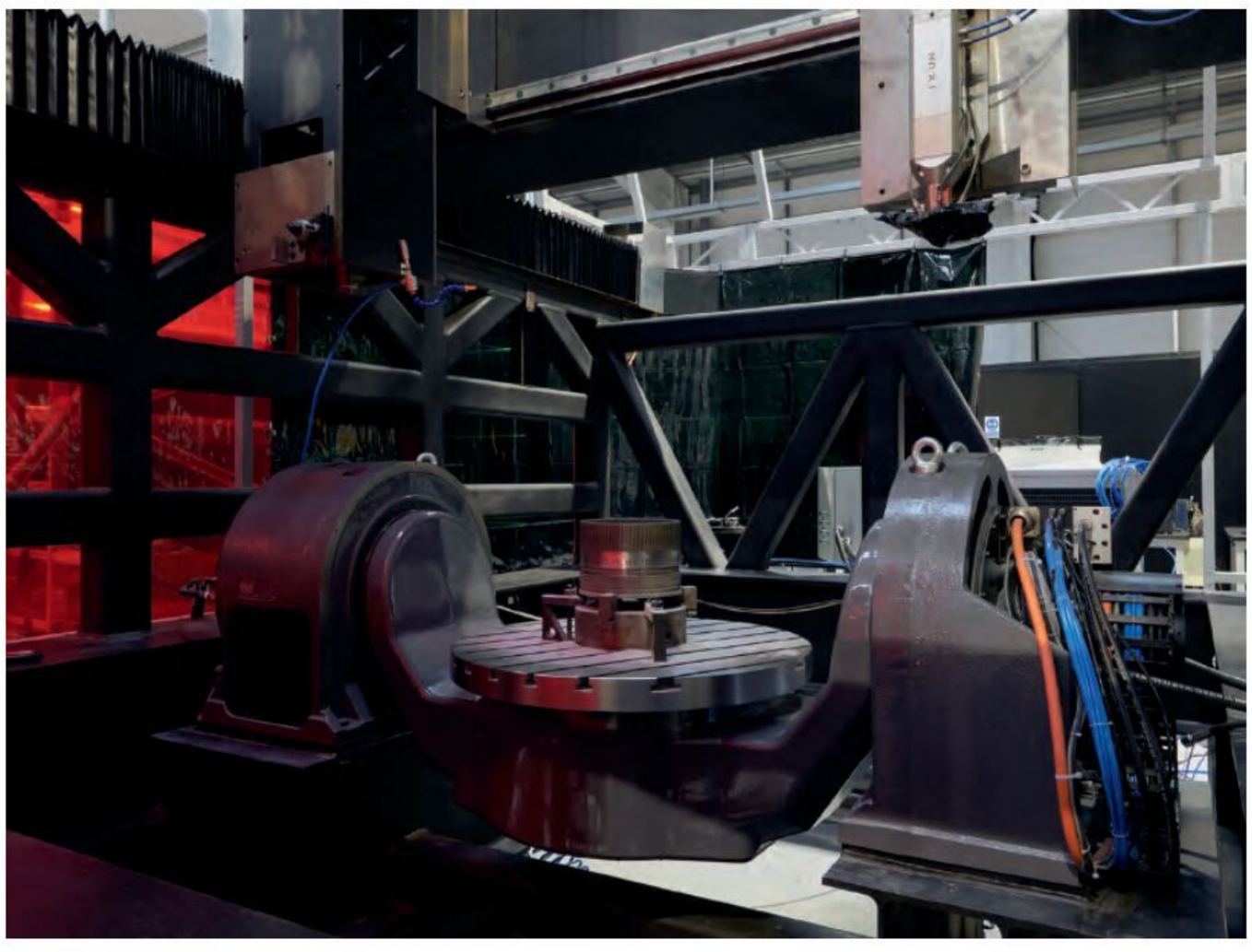
PHOTOGRAPHY: BENEDICT REDGROVE

↑ A rocket nose-cone (L), and propellant tanks (R) in Skyrora’s Vehicle Assembly Building in Cumbernauld.

↓ A tank containing hydrogen peroxide for the Skyrora XL’s second stage. Its third stage will attach to the left side.







↑

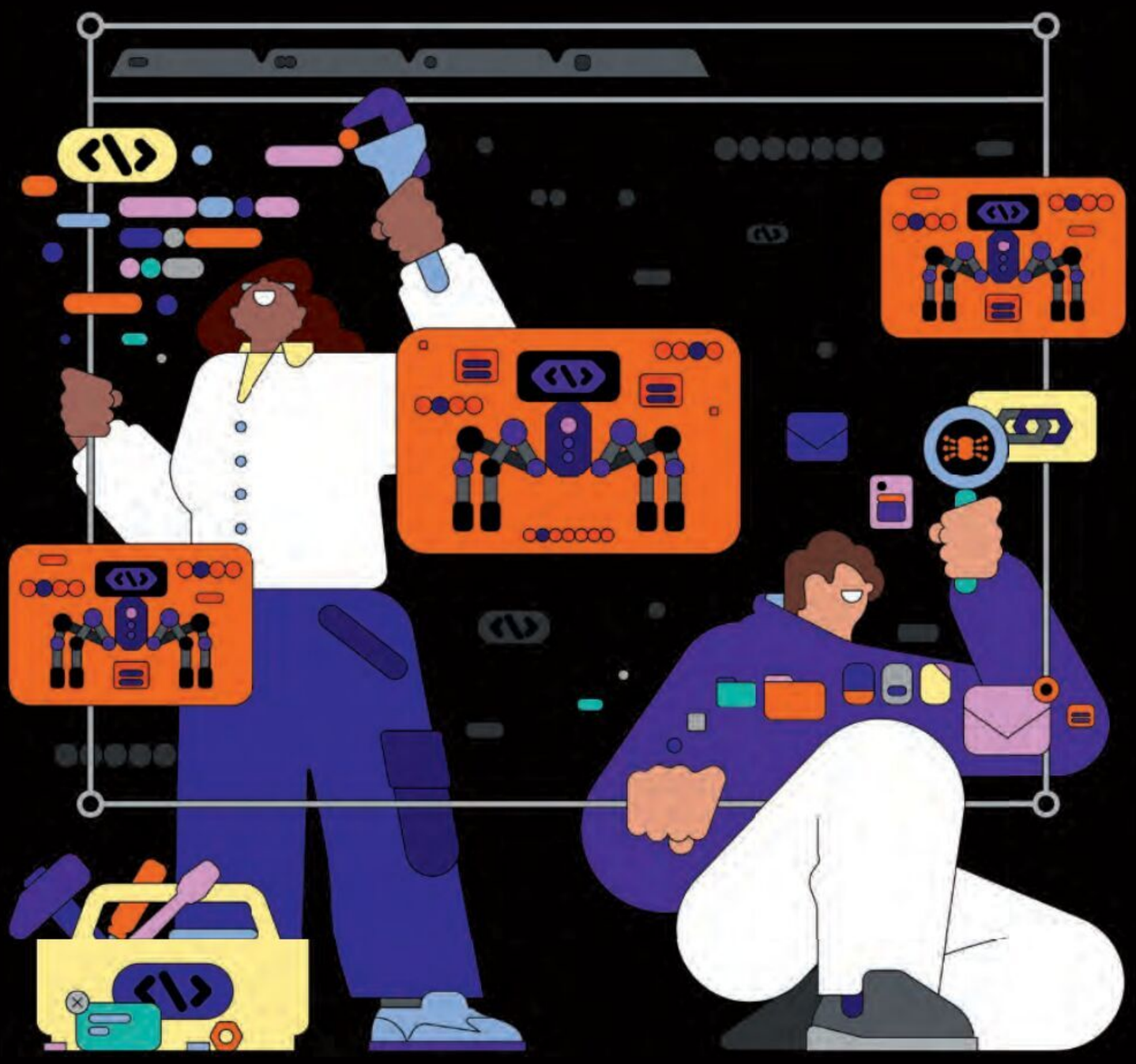
Third-stage pressure tanks. The circular frame on top is where the satellite payload sits.

→

Skyprint 2 is Skyrora's 3D printer, enabling it to print components on demand via a laser head.

PHOTOGRAPHY: BENEDICT REDGROVE

We spend more of our lives in a web browser than ever before. That makes it an alluring target for hackers, but also a vital line of defence.



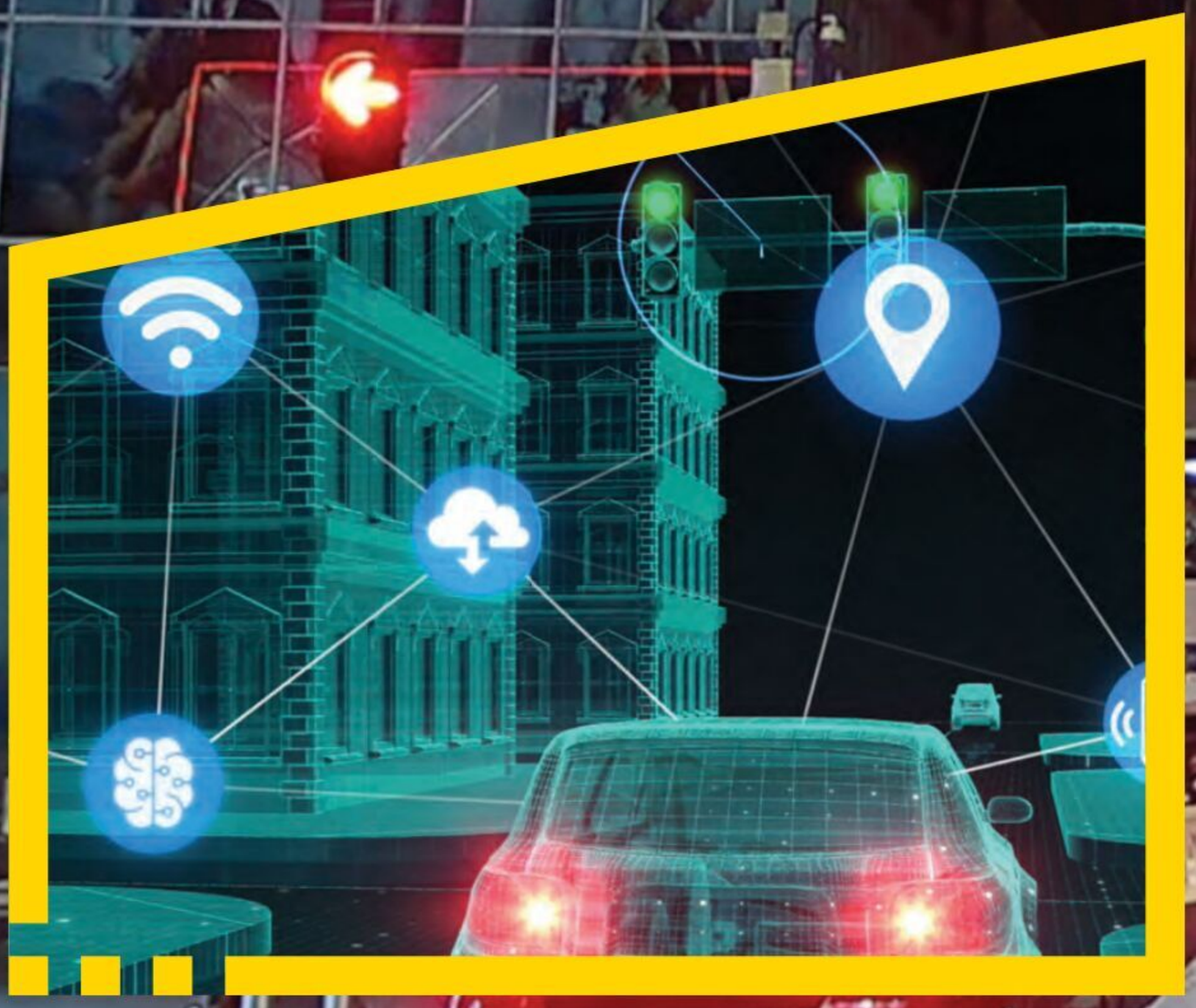
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Sections of the Skylark L, Skyrora's suborbital vehicle. The black cylinder is an oxidizer tank for hydrogen peroxide.

A space-bound taxi service implies regular rocket launches. But routinely sending a payload beyond the Earth's atmosphere will always be a technological and physical feat, says Euan Clark, project team lead at Skyrora. "Software and hardware across multiple stages all need to talk to each other and then communicate with us on the ground. Once you get one launch right it becomes easier, but ten successful launches in a row doesn't mean something else can't happen."

The Skyrora XL's first stage, still in development, is the main body of the 22.7-meter rocket, igniting and lifting the vehicle. Its second stage, which has now completed its testing, carries the payload past the edge of space. Unlike most rockets, the vehicle then has an extra, third stage that means the payload's placement can be fine-tuned up to 1,000 kilometers in altitude. "All of the stages are guided by the engines, with the avionics knowing where the satellite needs to be positioned in space," explains Clark. "The fuel is a mix of kerosene and high-test peroxide, meaning the third stage doesn't need sparks to reignite."

Both the first and second stages are reusable, returning to Earth by parachute. Skyrora's fuel requires less energy than SpaceX's cryogenic engine, meaning it has improved mobility, a lower cost of maintenance, and a gentler liftoff for a wider range of weather conditions. "We're flexible with our launches," says Levykin. "We have a global launch complex and tech for even bad weather."

Skyrora is also developing Ecosene, proprietary technology that converts unrecyclable plastic waste into high grade aerospace fuel, as well as 3D printing that enables all its rocket components to be manufactured in-house. Clark says satellite maintenance can then be provided through the Skyrora XL's special third stage. "If one satellite in a constellation is broken, we can go up and repair or replace it."

According to the Union of Concerned Scientists Satellite Database, there were 5,465 artificial satellites orbiting Earth by May 2022. But Levykin says there's enough space in outer space; he contrasts it to the nearly 100,000 vessels that currently skim the ocean. "Unlike most ships on water, orbiting satellites don't have to operate on the same layer. So, even if they increased in number by ten-fold, it's nothing."

Levykin predicts that as satellites grow in volume and importance, manufacturers and governments may intervene further; the former could introduce collision avoidance systems to limit space debris; the latter could create international borders in space, akin to maritime boundaries.

"New space is the next era of technology," says Levykin. "Eyes in the sky are the future, alongside new connectivity, data, and ideas. Space is impacted by Earth's geopolitics: you want your own capabilities and transport to play your own part."



The Skyrora XL's second stage contains three spherical pressure tanks. The rocket can hold 50,000kg of fuel.

PHOTOGRAPHY: BENEDICT REDGROVE

ALEX CHRISTIAN *(@alextchristian) is a culture, technology, and business writer.*

BREAKING THE LOOP: OUR AT-RISK INTERNET CABLES

The Asia-Africa-Europe-1 cable runs 15,500 miles along the sea floor, connecting Hong Kong to Marseille. As it snakes through the South China Sea and toward Europe, it connects more than a dozen countries—when it was cut on June 7, millions went offline.

The cable was severed where it passes over land in Egypt. The impact was immediate: among other countries, Ethiopia lost 90 percent of its connectivity; Somalia 85 percent. Cloud services run by Google, Amazon and Microsoft also experienced outages.

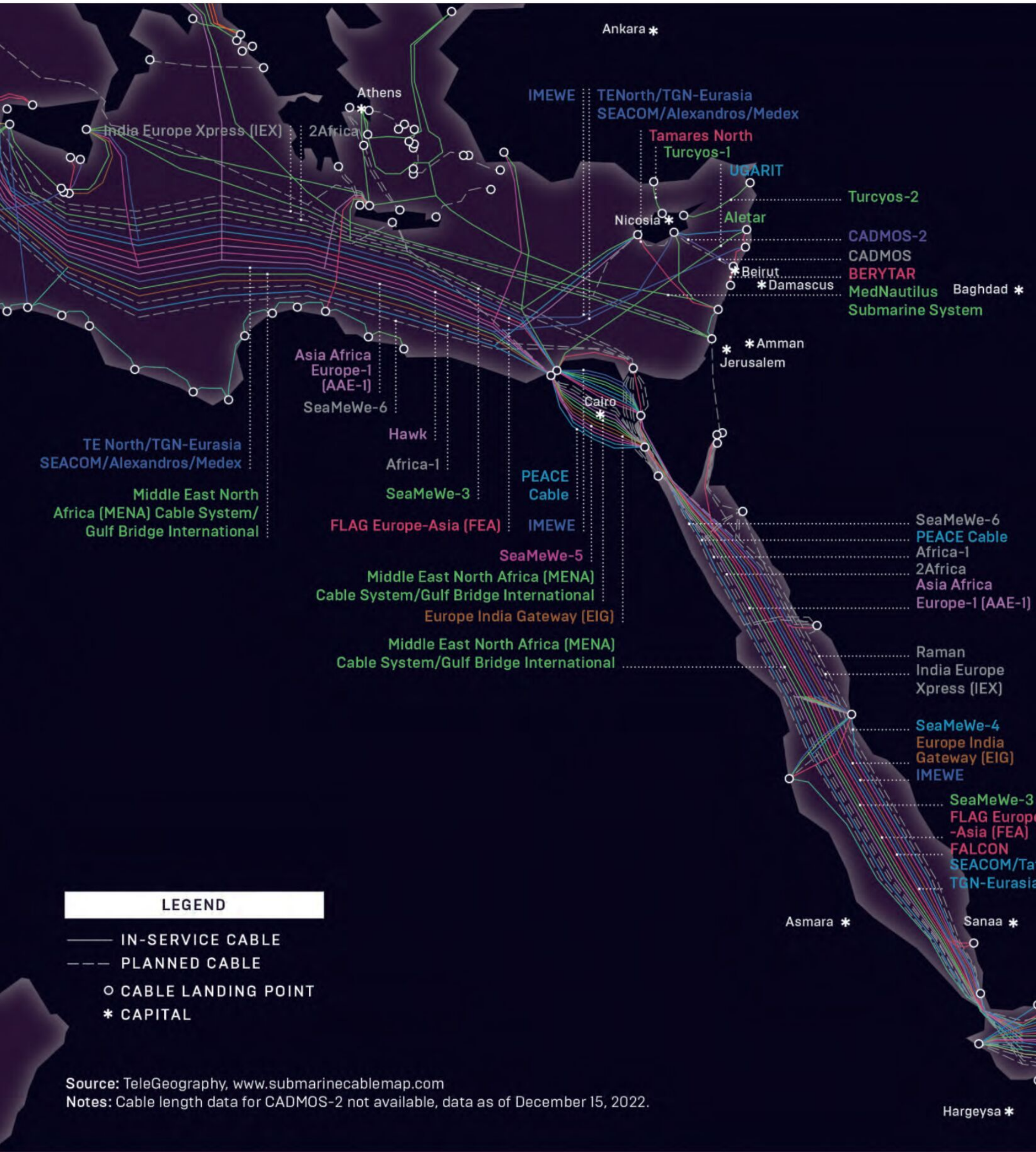


ILLUSTRATION: TIZIANA ALOCCI

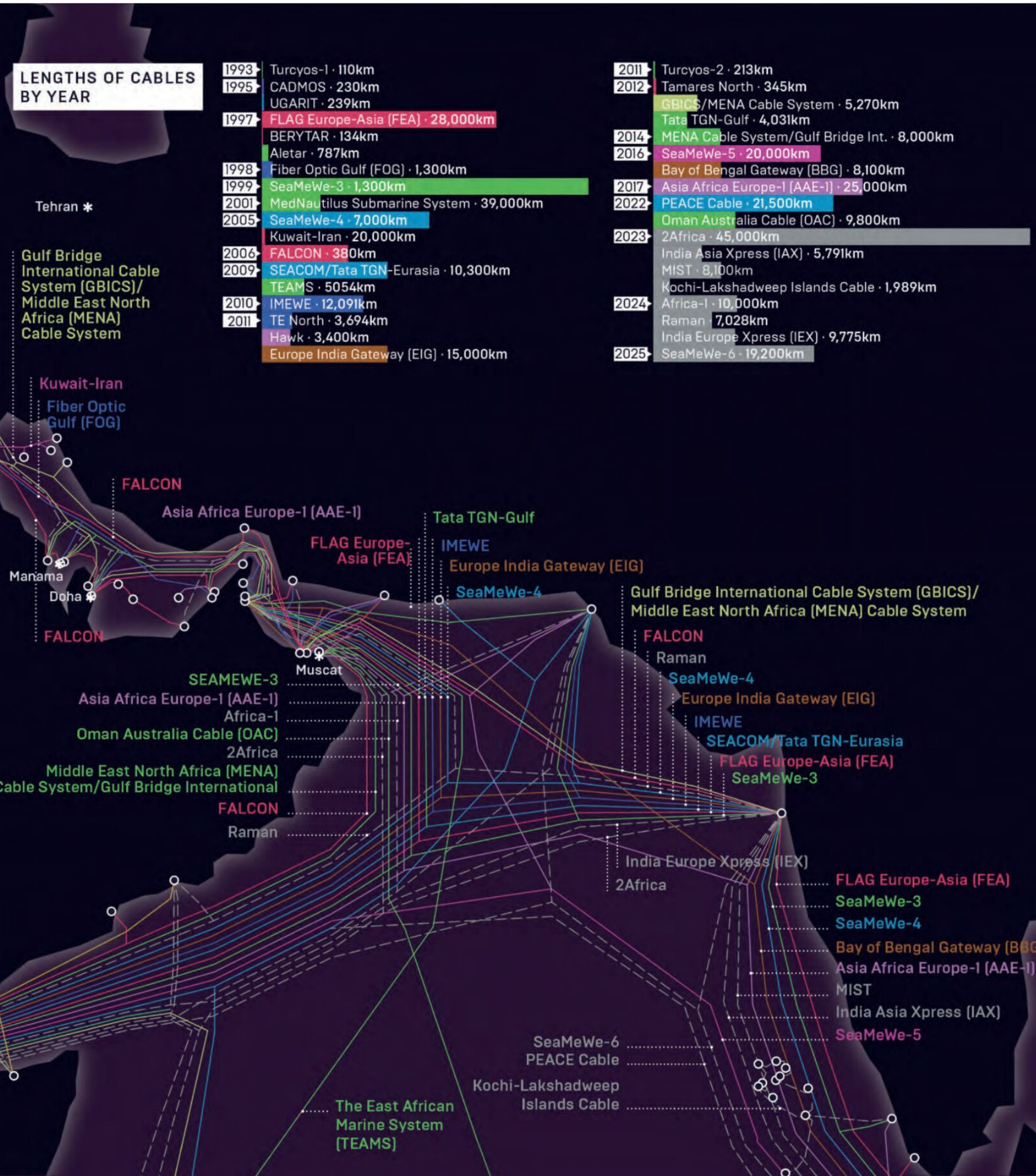
Source: TeleGeography, www.submarinecablemap.com
Notes: Cable length data for CADMOS-2 not available, data as of December 15, 2022.

While connectivity was restored in a few hours, the disruption highlights the fragility of the world's 550-plus subsea internet cables, as well as the outsized role Egypt and the nearby Red Sea have in the internet's infrastructure.

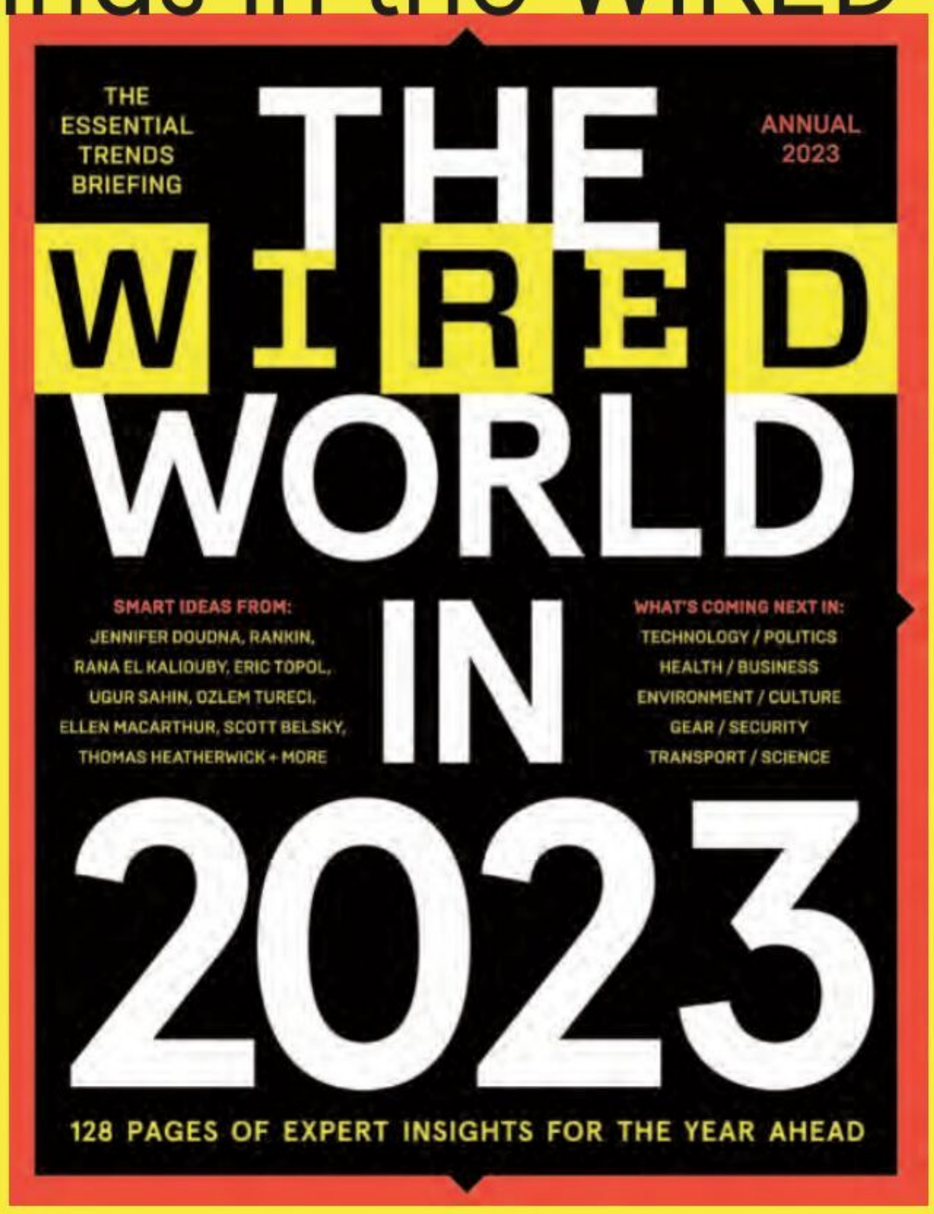
The global network of underwater cables carry the majority of data around the world, eventually linking up to the networks that power cell towers and Wi-Fi connections. Sixteen of these submarine cables—which are often no thicker than a hosepipe and are vulnerable to damage from earthquakes and ships' anchors—pass 1,200 miles through the Red Sea before they hop over land in Egypt to get to the Mediterranean Sea, connecting Europe to Asia. The route is one of the world's largest internet chokepoints and, arguably, the net's most vulnerable spot.

"Where there are chokepoints, there are single points of failure," says Nicole Starosielski, an associate professor of media, culture, and communication at New York University. "Because it's a site of intense concentration of global movement, it's more vulnerable than many other places."

MATT BURGESS *is a senior writer at* WIRED, *specializing in data and security.*



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Aaron Solomon and Jed Hackling aim to make their startup, Ambl, the Uber of restaurants.

FOODIE FIGHTERS FOR FREE TABLES

'Reservation culture' is the bane of the spontaneous night out, but a new app for walk-ins could help both diners and restaurants

Londoners love a good time, but a great night out usually requires some pre-planning—booking that fancy Mayfair restaurant at least three weeks in advance, for instance, or getting on the guest list at a trendy Shoreditch bar. But what if you could turn up on the spur of the moment and get seated almost immediately?

This is the inspiration behind Ambl, a new app that enables users to make last-minute reservations at many of the capital's most in-demand bars and restaurants, including Hawksmoor, Bob Bob Ricard and The Alchemist. It's the brainchild of long-time friends Jed Hackling and Aaron Solomon, the latter of whom experienced a "light-bulb moment" after ringing up countless venues one day, desperately trying—and failing—to make a booking for a party of seven.

Previously, Solomon and Hackling worked in financial services and tech recruitment respectively, but one might argue that the duo have long had a taste for the hospitality industry. After all, they set up their first foodie venture together when they were just 13, selling ice creams in their school canteen and raking in a cool £600 before they were ordered to shut down. After leaving school and going their separate ways, the pair teamed up again almost a decade later to launch Ambl in London during October 2022.

According to the duo, Ambl is modeled after convenience apps like Deliveroo, Just Eat, Getir and GoPuff. "It's all about solving for the on-demand society we live in," Solomon says. Indeed, they hope Ambl will become the "Uber of restaurants".

Upon launching the app, users can browse establishments within a two-mile radius with real-time availability, and filter results according to party size, type of venue, and distance. Then, they can hit "Search" to view a map of available places, or "Broadcast" to send a request to all registered venues that meet their criteria.

The platform is free to use for diners, while businesses are charged £1 per head—a small price to pay, considering that cancellations and no-shows cost the UK hospitality industry £17.6 billion a year.

"We've spoken to a lot of venues to find out what their pain points are, and built a really simple solution," Hackling says. Staff can share available capacity in just a few clicks, and the app's autoresponder does the hard work for them by replying to customers and confirming bookings. "We're essentially providing them with a screen that shows them a marketplace of people in the area, which they wouldn't otherwise see," Solomon adds.

While the 105 establishments currently featured on Ambl are all located within central London's Square Mile, another 1,200-plus venues across the city are keen to come on board. A full London roll-out was expected by the end of 2022; thereafter, the duo have set their sights on other markets across the UK and even worldwide. "A key thing for us is scalability. We've built everything—from the technology to the processes—to be able to scale quite aggressively. If we need to onboard 10,000 new users all of a sudden, we can," Hackling says. To this end, they've secured £2.3 million in seed funding—courtesy of big-name investors including restaurateur Jon Spiteri and serial entrepreneur Mark Gordon—which will be used to support their launch efforts and build out schemes that reward their venue partners.

From a humble ice-cream stall to a multi-million-dollar tech startup, Solomon and Hackling have certainly come a long way. And true to Ambl's ethos of spontaneous living, they're seizing the moment. "We were both previously in amazing jobs, and my parents went mental when I told them I had quit to start an app. But we'll probably never get a chance like this again—to be part of a business that might one day become a household name," Solomon says. "We've got a clear vision, and that's what keeps us going." *ambl.co*

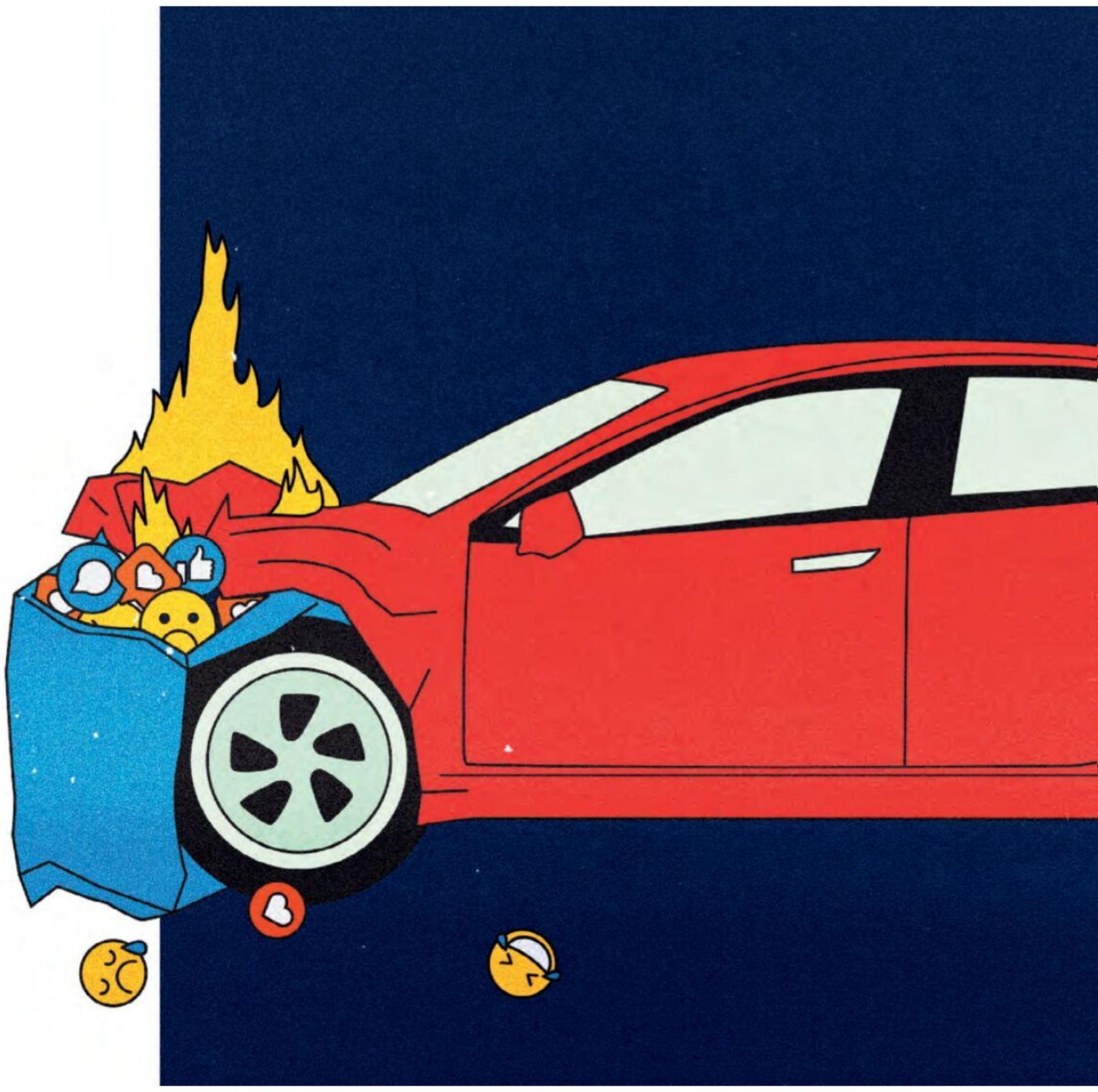
DELLE CHAN *is a London-based writer and editor, and a* WIRED *contributor.*

PHOTOGRAPHY: DEAN CHALKLEY

A TWEET BEFORE DYING

The revolutionary internet is over, and we don't have much to show for it. A new start is out there, somewhere

The revolutionary internet is about to smash into a burning rubbish skip filled with social platforms and tired memes. But at least we'll get a fresh start ...



I find it a good philosophical exercise to imagine the last tweet. It could come centuries hence, when a cryptobot offers a wistful adieu to another cryptobot, or in 2025, when Donald Trump, the newly inaugurated president for life, pushes the big electromagnetic pulse button on the Resolute desk. Or it could come in a few months, when Elon Musk realizes that aggregating human despair has no upside, regrets plowing his electric clown car into a social media goat rodeo, and shuts the whole thing down with a single "lol." (Way to own the libs.) What then? We'll all move over to some Twitter replacement like Mastodon, hundreds of millions of us, and ruin that too? Sigh.

Lately it feels like the last tweet could come any day. The whole tech industry—by which I mean the cluster of companies that sell code-empowered products to billions of humans—is in extraordinary decline. The Zuckerverse has everything but users, which means Meta must come up with ever more creative ways to ruin Instagram and/or society. Microsoft, Amazon, Google—their stock charts look like Niagara Falls in profile. At least $3 trillion has ridden over the cataracts in a barrel. When your brand is infinite growth, investors don't like to see failure. It has become possible to imagine not just the last tweet but also the day when Facebook exists only as a multi-exabyte ZIP file in archival storage, or when Googling is an interactive exhibit at the Internet History Museum.

Of course, truly giant things—at the scale of social media platforms, religions, and nation-states—don't really die. They deflate like air mattresses, getting soft at the corners and occasionally waking you up to pump them. The entities that dominated my childhood, AT&T and the Soviet Union, seemed at

one point to have given up the ghost. There was rejoicing: Now a million new innovative companies can flourish! Now democracy will spread everywhere! Both were stripped for parts—and those parts eventually recombined into new, enormous forms, like beads of mercury finding each other on a plate. A re-blobbed AT&T ended up buying a ton of things, including Time Warner, giving it control of both the piping and the content. The former USSR, well … There is always someone with a fantasy of getting the band back together, even if the consequences are terrible.

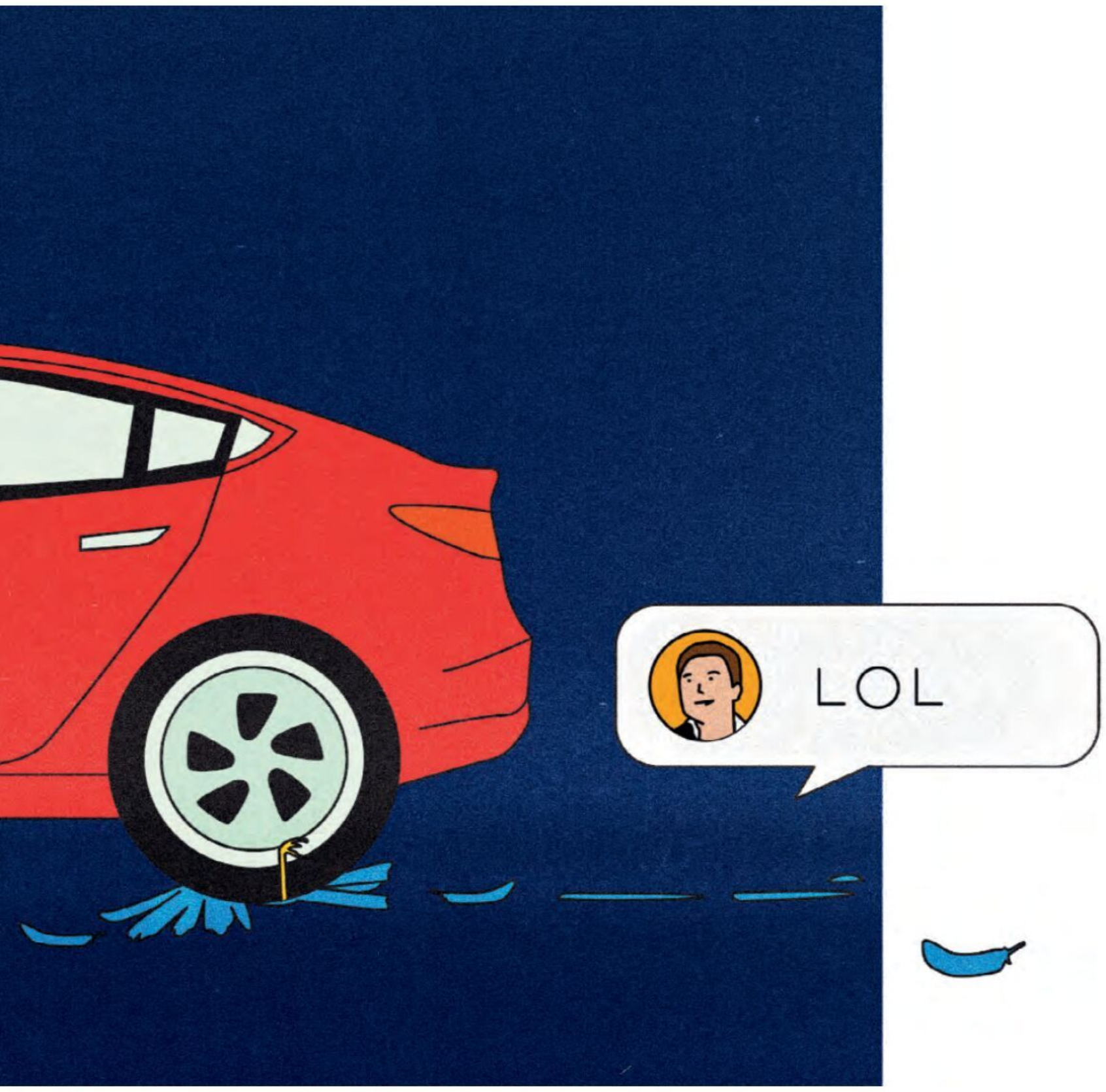


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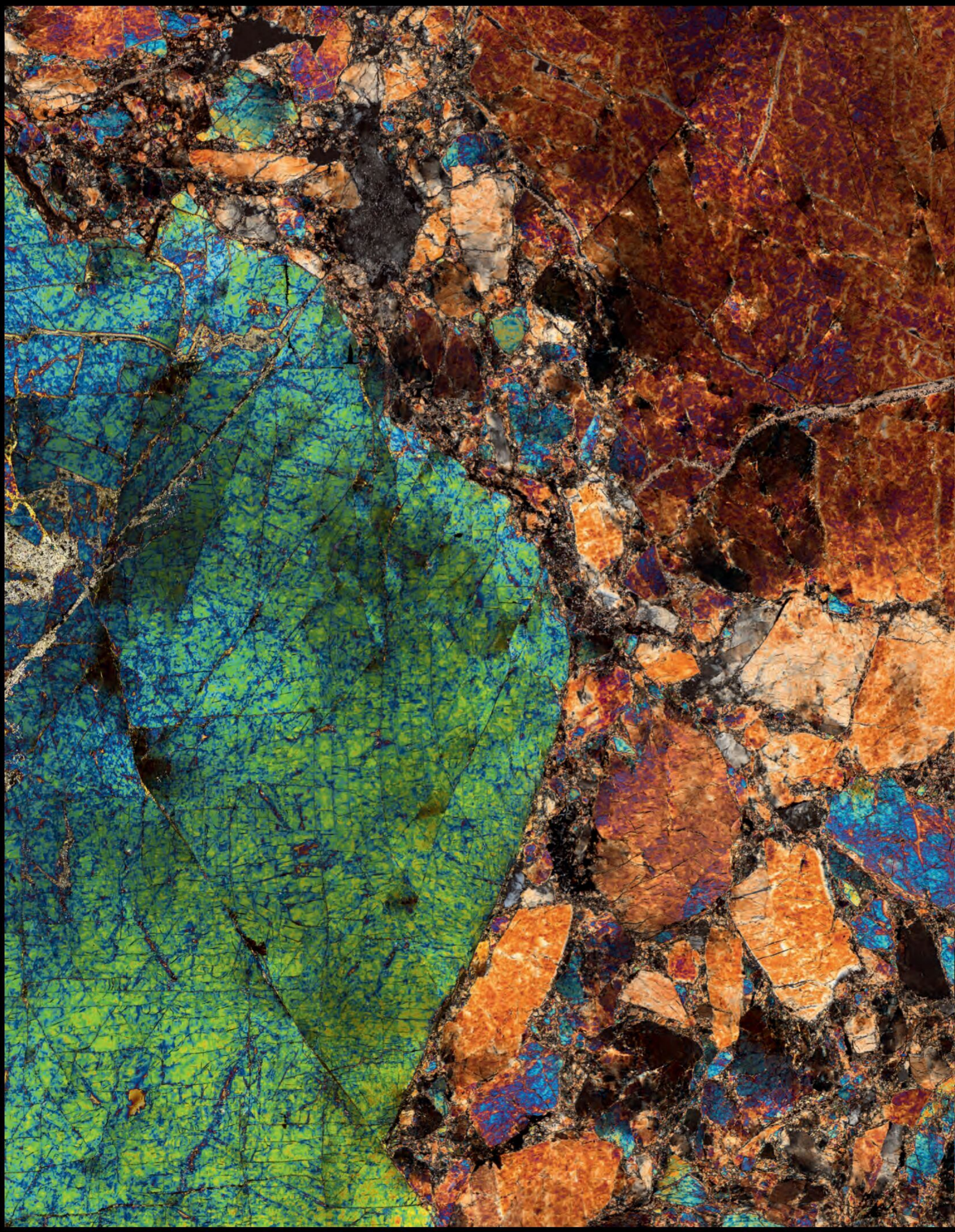
Like a lot of you, I imagine, I have been looking at this shifting world and finding the changes pretty rough to behold. Recession, authoritarianism, nuclear posturing, a weirding climate—these pop up unbidden in the feed, like the time Apple put U2's *Songs of Innocence* on everyone's iTunes without asking. When future historians write books about this era, I feel pretty sure they'll pick titles like The Fracture, The Fraying Knot, Hope Undone, Leviathan Triumphant, A Web Unwoven, stuff like that. (If they're Q-storians, they might go with The Gathering Storm.) Obviously they'll include the last tweet, whatever it is. How else are they supposed to demarcate the end of the glorious web content revolution?

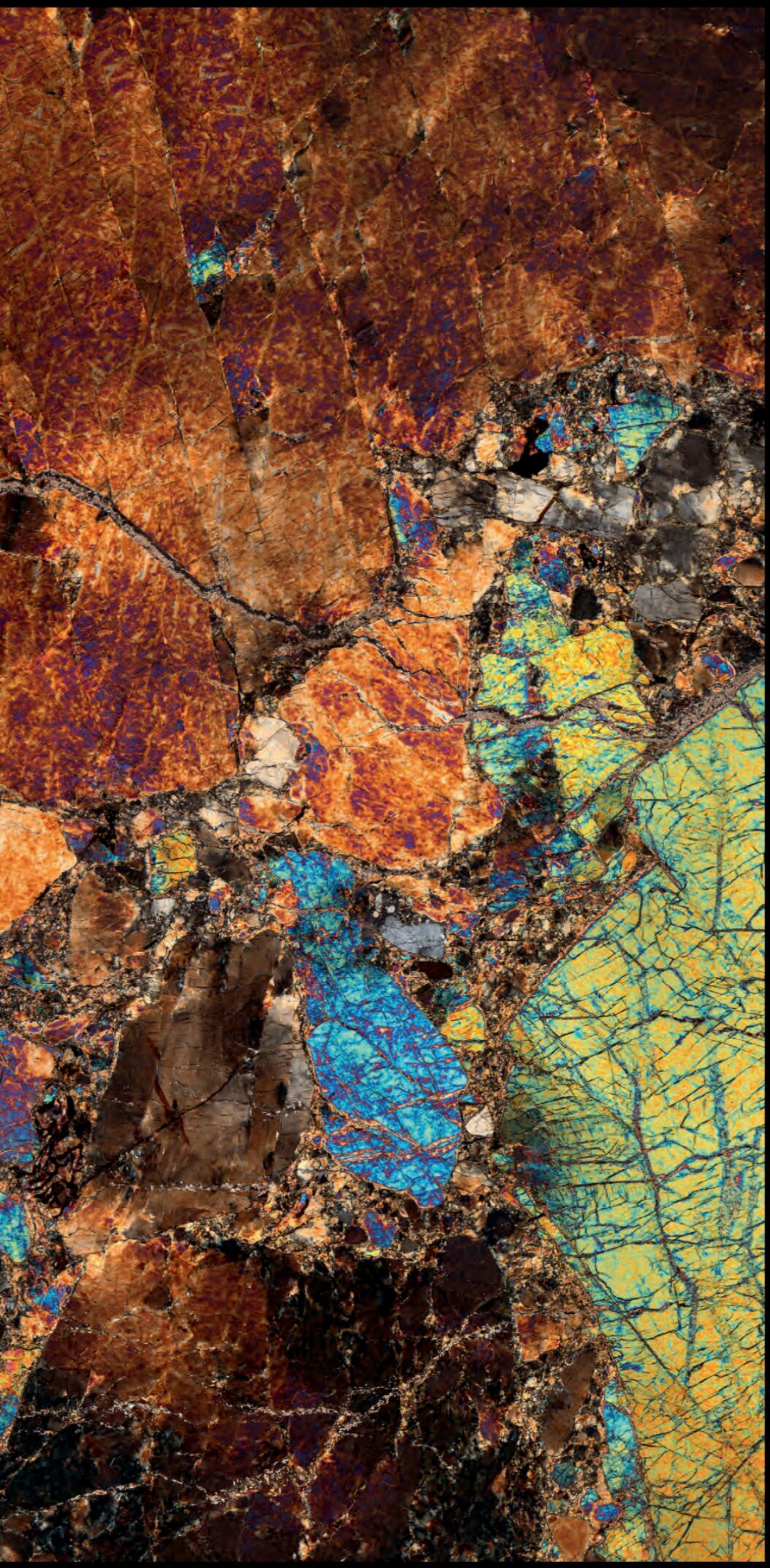
Personally, I'd begin and end that history with the House of Windsor. When Princess Diana died in 1997, the web was just coming into its own. Cable TV dominated, but online news—the linking between articles, the packaging of stories on homepages, the rich dithered GIFs—suddenly began to feel real and relevant. The tragedy was urgent and shocking and unscripted, and for an early web enthusiast it felt like the big leagues. But when Diana's former mother-in-law died, a quarter of a century later, the part the internet played felt predictable. We knew to expect the tweets against colonialism and against anti-colonialism. We understood implicitly that the funeral horses would be memed. We had a vocabulary for the takes, hot takes, cancellations, and dunks. We posted through it.

Rip the revolutionary internet, 1997–2022. I'm grieving a little over here. But life must go on, despite who wins the next election, who owns Twitter, and how ridiculous the metaverse might be. That's why every morning, sometimes before breakfast, when I am in despair, I remember the three letters that always bring me comfort: PDF. And then, when I can, I go digging. I read about Gato, a new artificially intelligent agent that can caption images and play games, or the mathematics underlying misinformation, or "digital twins," which are simulations of real-world things like cities that consulting firms seem able to sell these days. One site, scholar.archive.org, has PDFs going back to the 18th century. It's empowering to look for this stuff instead of waiting for it to be socially discovered and jammed into my brain.

This was the original function of the web—to transmit learned texts to those seeking them. Humans have been transmitting for millennia, of course, which is how historians are able to quote Pliny's last tweet ("Something up w/ Vesuvius, brb"). But the seeking is important, too; people should explore, not simply feed. Whatever will move society forward is not hidden inside the deflating giants. It's out there in some pitiful PDF, with a title like "A New Platform for Communication" or "Machine Learning Applications for Community Organization." The tech industry said we had it all figured out, but we ended up with a billionaire telling us to strap on a helmet (space or VR) while the rising seas lap our toes. So now we have to try again. Now we get to try again.

PAUL FORD *(@ftrain) is a writer, programmer, and software entrepreneur. He lives in Brooklyn.*





PHOTOGRAPHY: COSMICMICROSCAPES.COM

HIGH IMPACT

Photographer Neil Buckland captures the mosaic of minerals hidden inside meteorites

When Neil Buckland, an artist based in Seattle, met a geologist named Tony Irving a few years ago, he had no idea it would launch an extraterrestrial collaboration. Buckland was at the University of Washington, photographing ultrathin slices of meteorite for a project Irving was working on. The cut space rocks didn't seem particularly exciting at first. Then Buckland peered at the 30-micron-thick samples through a pair of polarizing filters. He was stunned by the vibrant collage of hues. Inspired by the photographic possibilities, Buckland went back to his studio and got to work designing a camera system built around a microscope lens attached to a Pentax DSLR. To create his images, he captures a 2-millimeter-square section of a sample at up to 40,000X magnification, then moves the camera slightly and shoots another square. After capturing 300 to 400 of those, he stitches them all together into a photo that can be displayed at up to 12 feet wide. "It's like a cosmos in a pebble," Buckland says. "From an artistic standpoint, I try to show the images as big as I do and as detailed as they are to create that existential shift in perspective."

The polarized light can reveal different minerals within the samples. If a meteorite is rich in olivine, like the one shown here, the light brings out greens, oranges, and blues. For scientists, the configuration of minerals can hold clues to a meteorite's origins, such as whether it came from an asteroid collision a billion years ago or was ejected from a massive impact on another world with a particular mixture of atmospheric gases. They're also great to look at if you just want to space out.

Staff writer **RAMIN SKIBBA** *(@raminskibba) covers all things space for* WIRED.

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THE
NEW

i7

FORWARDISM

EVERY MOVEMENT
CREATES ITS OWN ICON.

#bornelectric

TAKING THE LEAD

with the new BMW i7

ILLUSTRATION: LIZZIE GILL



BMW's i7 proves that going electric is all gain and no pain

BMW wants to get to a better future ahead of schedule. It calls this idea "Forwardism"—and the new all-electric i7 is the movement's flagship

The future of cars is all-electric—but accelerating the transition away from combustion engines means re-imagining and re-engineering legacies, not pretending they don't exist.

Consumers understand what certain brands and models stand for—they are a hard-wired language and hierarchy of trust and aspiration. And the shift to electric should become part of that history, not deny it. This isn't about complacent nostalgia or trading on the past, but the quickest and most effective way of upending expectations and changing minds.

To achieve that, all-electric updates of iconic models must offer something compellingly, thrillingly different. Even when they share the same design language, the electric experience should feel radical and revelatory. BMW calls this idea "Forwardism" and it achieves its fullest expression in the new BMW i7, the first all-electric version of 7 Series, its flagship luxury saloon.

"Digitize it, electrify it, make it a bit bigger. That's the answer" BMW CEO Oliver Zipse has said. BMW has achieved much more with the i7, the most technologically advanced and flat-out luxurious car it has ever produced. Zipse calls it "an icon of a new movement".

BMW says the i7 was designed from the inside out, which makes sense. The vehicle is a 5.1m long, smooth-cruising cocoon, so the cabin experience is at least as important as the driving experience. But even though the interior deploys an impressive array of luxury materials, sensual touch points and home comforts, it pushes well beyond the buttery leather and polished mahogany luxury tropes.

BMW has used elaborately quilted cashmere and leather, or the vegan leather alternative Veganza, in the i7 cabin, and the effect is warming, immersive and domestic. Off-setting that, however, is the cabin's digital landscape, offering all sorts of information, driver and passenger options, and entertainment.

Up front, the sleek Curved Display—combining a 12.3in instrument display

"All-electric takes on iconic models must offer something compellingly, thrillingly different"

with a 14.9in infotainment touch screen, and running BMW's remarkable iDrive and 5th-generation operating system—is more seamless panorama than instrument panel. BMW calls this "shy tech"—obtrusive physical knobs and dials have been digitized—and iDrive's crisp, calming design makes for discreet service, not needless distraction. And, of course, voice-activation software means you can keep touchscreen menu-drilling to a minimum.

Below the Curved Display, the crystalline, backlit Interaction Bar works in sync with iDrive's My Modes options, allowing for micro-management of cabin mood and ambiance. It also houses touch-sensitive control panels for adjusting the ventilation and climate control, activating the hazard warning lights, and opening the glove compartment as well as saying hello and goodbye with specific light sequences.

The i7 delivers more in the way of mood and multi-sensory pleasures, but it also employs advanced technology to make driving easier and safer. The



i7's new Augmented View function adds useful information to a live video stream of the driver's forward perspective, shown on the information display behind the steering wheel. Approach a particularly confounding intersection, and an animated directional arrow will appear, integrated into the live feed. No more trying to match sat nav abstractions with gnarlier real-life situations.

Manoeuvre Assistant meanwhile can store and automatically repeat up to ten particularly tricky parking or exiting moves you make regularly. You can even get out of the car and take remote control using the BMW smartphone app.

First launched in 1977, and now in its seventh iteration, BMW's 7 Series has always been designed to provide equal, if different, rewards whether you are driving or being driven. And the rewards in the back seats of the new i7 are rich.

For better or worse, modern life is increasingly focused on screen time. And in the i7, that means *big screen* time. Should the passing landscape or the limited options of "I spy" get a little dull, passengers, in what Zipse calls the "private lounge", can take in a movie, streamed or downloaded, on a fold-down 31.8in 8K "Theatre Screen''. They can also use it for game-playing and the most "*Succession*-y" Zoom calls imaginable.

The screen has Amazon FireTV built in, while enveloping sound is (optioning dependent) delivered by the 36 precision placed speakers of the Bower & Wilkins "4D Diamond Surround Sound" system. Speakers integrated into doors get their own elegantly perforated metal covers, while speakers in the outer head restraint and bass shakers in the backrests help deliver a truly immersive, bone-deep audio experience.

All of this unfolding drama—including lowering blinds for proper cinema conditions—can be managed from a 5.5in touchscreen control panel built into the door. And if you're sitting behind an unoccupied front passenger seat, you can recline your seat to a best-in-class 42.5-degree angle, and properly put your feet up. The seat also offers nine different



PHOTOGRAPHY: JAMES MASON

Left: The WIRED Impact main stage played host to green innovators.

massage functions, just to ensure you are properly relaxed as you watch.

To burnish the car's cinematic credentials, BMW drafted in legendary soundtrack composer Hans Zimmer to create 7 Series-specific soundscapes. (The upfront Curved Display can also play video on demand when parked.) And should you need a break from on-screen entertainment, the light threads woven into the i7's new Panoramic Sky Lounge LED roof offer light shows, from the explosive to meditative.

Even if you're not driving, you want to feel the car move, and the i7 customer is after a particular kind of refined surge. The car's 544-horsepower electric powertrain, now up to generation five, delivers new levels of near-silent power and torque, a precisely engineered, hushed rush of energy. The i7 will quietly thunder from 0-62 mph in 4.7 seconds, smoothly canter to 150 mph, and has an impressive range of up to 387 miles.

The BMW Maps navigation system automatically calculates a charging-optimized route if your final destination is out of range, with dynamic route calculation factoring in precise real-time traffic data. The system also estimates charge level at recommended charging stops, and the charging time required to reach your target charge level.

Exterior-wise, the i7 talks the BMW design language, but with all kinds of new accents and flourishes. The body is muscular and monolithic, and the iconic kidney grill is enlarged and features illuminated contours at night. The upper section of the split-level lights is (in some models) cut from Swarovski crystal glass. And crystal is a recurring material and design motif of the i7, inside and out.

Adrian van Hooydonk, Senior Vice President BMW Group Design, calls the i7 "a perfect expression of modern luxury, human-centric, electric and tech magic". And much of that tech magic will eventually be sprinkled on cars lower down the price and prestige ladder.

Of course, the i7 is also the most glamorous of ambassadors for BMW's more responsible approach to mobility. The obvious thrust of the i7 is that there is no sacrifice involved in going all-out electric—not in range, and certainly not in regards to speed or comfort.

Behind the scenes, BMW is re-engineering its supply chain, manufacturing and energy use around circularity principles. Upfront, it is proving that all-electric models can deliver everything a combustion engine alternative can, and in many areas more and better. More than that, cars such as the i7 answer to a new, more progressive kind of aspiration that cares about impact in every way. This is an aspiration that values advanced technology, the highest quality materials, and the most sophisticated (and, yes, sometimes the simplest) of comforts. But it is also an aspiration to be part of a broader movement—one that is advancing towards a better future, for everyone.

Adrian van Hooydonk calls the i7 "a perfect expression of modern luxury; human-centric, electric and tech magic"





Top: WIRED Impact highlighted green challenges. Right: exploring the new i7.



The drive behind BMW's electric surge

BMW's Roberto Rossetti on the car giant's push towards more planet-friendly mobility, from 'urban mining' for recyclable parts, solar farms in Oxford, the potential of hydrogen power and the development of plant-based upholstery

BMW has long been in the advanced guard of auto electrification, launching the game-changing i3 back in 2013; now the i7 is the flagship model of an ever-growing fleet of all-electric models. During 2023, the Munich-based car giant will offer 13 electric powertrain cars, with a strategy of creating electric and combustion engine versions of the same models across its entire range.

BMW-owned Mini and Rolls-Royce are also producing electric vehicles. The fully electric Mini was its best-selling model of 2021 and, in 2022, Rolls-Royce launched the Spectre, its first fully electric car.

The company says it will have sold 2 million battery electric cars by 2023, and that more than half of its sales will be electric vehicles by 2030. It is also testing a fleet of hydrogen-powered vehicles, with a view to putting some into production by the end of the decade.

Roberto Rossetti, BMW's Head of Vehicle Life Cycle and Product Sustainability, spoke at the recent WIRED Impact conference in London. He made clear that the company's forwardism drive goes far beyond, or behind, the "use phase".

BMW has already reduced greenhouse gas emissions in its own production facilities by 80 percent and uses renewable energy across its production network, operating wind farms at its Leipzig plant and solar farms in Oxford and San Luis Potosí in Mexico. It uses hydropower in Austria and Estonia, and says the company's first green hydrogen pipeline has just gone online. BMW is the first German car maker to join the Business Ambition for 1.5°C campaign, led by the Science Based Targets initiative, and Rossetti argues that green hydrogen will be key to transitioning from fossil fuels across most industries.

BMW is working with suppliers to reduce greenhouse gas emissions across its supply chain, to increase the use of recycled and re-used materials in its fleet and move, as far as possible, towards circularity. Rossetti admits that current BMW vehicles contain only 30 percent secondary or recycled materials, but the aim is to push that to 50 percent. "We see old scrap vehicles as material feedstock for the production of new vehicles," he says. "We call it urban mining."

Rossetti says the new i7 contains 150kg of recycled aluminum, and key components made entirely or partly out of recycled plastic, adding that BMW has reduced CO_2 emissions from the manufacture of upholstery by 85 percent and from high voltage battery cells by 45 percent.

The company is also working with startups developing plastics derived from biomass, and incorporating flax as well as plant-based upholstery. It is already using recycled ocean plastics in floor mats. "When developing a new component, we always try to use secondary recycling material first, and then fill up the rest with primary material," Rossetti says.

ILLUSTRATION: LIZZIE GILL

Top: Roberto Rossi, BMW's Head of Vehicle Life Cycle and Product Sustainability

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HOW TO SAVE THE WORLD

2022

Just days before COP27, WIRED Impact gathered scientists, engineers, investors, campaigners, and entrepreneurs in London to discuss practical solutions to the most pressing challenges in climate change, migration, sustainability, and ESG. We profile some of the most creative sessions.

By Stephen Armstrong. Photography: James Mason

Additional reporting: Grace Browne, Joel Khalili & Matt Reynolds



Inna Braverman,
founder & CEO, Eco Wave Power

HARNESSING THE POWER OF THE SEA

It's an abundant source of renewable energy, but wave power is still dogged by the failure of its premature deployment

Wave energy needs to join the mix of renewables—but first, pro-wave legislation must be implemented.

Wave energy can produce 66 percent of the United States' energy needs, but is in danger of being ignored, Inna Braverman, founder and CEO of Eco Wave Power told Impact's morning session. Years of underinvestment, poor technology, nervous insurers, and angry environmentalists mean wave power's potential is not being harnessed.

"Wave energy can produce electricity 24/7, operates at night, or in the winter, or in cloud coverage," she explained. "There is 832 times more kinetic energy in the water than in air, meaning we can produce more electricity with smaller devices."

The problem, according to Braverman, is that early wave energy farms used large, heavy, floating generators that had to be tethered to the sea bed. They were expensive, vulnerable to storm damage and, with their presence on the ocean floor, disturbed the marine environment.

"Wave energy deployed too soon," she believed. Her solution is a light, smart, floater connecting to onshore structures like piers, breakwaters and jetties via flexible arms. As ocean swells move in, the floats' rising and sinking creates pressure harnessed by hydraulic cylinders which, when transmitted to land, spins a generator to create electricity. Most of the expensive infrastructure—generators, hydro motors, and accumulators—lies on land, shielded from bad weather.

Trials in the port of Jaffa, and in Gibraltar, have proved successful, and the company is opening its second power station in Israel and its third in Los Angeles. Braverman has signed deals in Europe and is lobbying policy makers in the UK and the US to create legislation to support the technology.

"The UK is one of the best countries in the world for wave energy, but there's no supporting legislation," she explained. "Government removed all the subsidies—but we are having conversations and, elsewhere, are backing legislation in places like New Jersey."

Ironically, oil companies might become one of her best customers: Total is in conversation with Eco Wave Power to deploy floaters on oil rigs, including those no longer in use. "The solution for the world's problem is combining all renewable energy sources together, which is why one of our recent patents involved adding solar panels on top of our floaters," she pointed out.

Braverman's desire for clean, safe energy is personal—she was born in Chernobyl shortly before the reactor disaster of 1986, and suffered a heart attack as a baby due to the resulting pollution. "My mother was a nurse," she explained. "She gave me mouth-to-mouth resuscitation until the ambulance came and saved my life. So, I got a second chance and I wanted to do something good with it. I believe that wave energy is definitely a good thing to do for the world."



Our addiction to plastics and synthetic chemicals is driving oil production—but there is an alternative.

The chemical industry consumes one third of the world's oil, and is an old, massive industry that's resistant to change and wary of outsiders, Mathieu Flamini, premier league footballer turned CEO of GFBiochemicals told the room—but change is coming.

"From shampoo to deodorant to paints, detergent, and even plastic chairs—everything is made from chemicals," he explained. "We need to create awareness that when you buy personal care items every day, there's a right product and a wrong product."

Besides GFBiochemicals, the conference also heard from FabricNano and Shellworks about a range of plant-based alternatives to polluting oil-based products. Flamini's company uses agricultural waste to create levulinic acid—a biodegradable organic compound that can be used instead of oil to create replacements for petrochemicals in everyday items, from personal care to industrial plastics.

"We are not going against the industry, we're partnering with the big players and large chemical groups to help them accelerate this transition," he told the room. "If you take a large player, it's difficult for them to think innovation will come from outside the company. This is

Mathieu Flamini,
CEO GF Biochemicals

REMOVING CARBON FROM THE CHEMICAL INDUSTRY AND BUILDING THE CIRCULAR BIOECONOMY

We urgently need a replacement for plastic. Non-fossil-derived alternatives can now finally compete in performance and cost



something new happening in the chemical industry."

London-based startup FabricNano, which raised £12.5 million from the likes of Atomico and actor Emma Watson in 2021, is harnessing enzyme reactions that usually take place in living cells, to create rivals to plastics—starting with biodegradable polyester. Typically, most of the proteins used in such enzyme reactions are destroyed or degraded in the production process, which makes bioplastics expensive.

"Bio-based plastics need to be at cost parity with things like PET plastic," Grant Aarons, the company's cofounder and CEO told the room. FabricNano's process mimics DNA in the way it handles proteins, offering a price point that's already attracted industry giant Sumitomo Chemical America.

Shellworks is focusing on plastic packaging, and its compostable organic polymer, Vivomer, is created by marine and soil-based microbes. It's already in the skincare packaging of beauty brand Haeckels' bottles and jars.

"If you throw the jar away, the very same microbes in the soil and the marine environment will see it, recognize it as its food, essentially, and break it down," the company's CEO and cofounder Insiya Jafferjee explained.

Change is still too slow, Flamini warned. "The regulator has to be more aggressive to protect people and planet. This is an old, massive industry—change takes time. The regulator needs to allow new molecules to enter the market faster. If it takes 10 years, we're not quick enough," he said. "But I like a challenge. I remember as a young kid being told I will never become a football player—and after many years of work, I became one. This requires the same dedication, hard work and resilience."

Evelina Olago believes that scaling climate-led investments is critical to sustainability.

When it comes to averting a climate crisis, we're running out of time—and while the solutions exist, they're not being funded, Just Climate's client director Evelina Olago told the afternoon session.

"Traditional capital allocation models mean that capital doesn't find its way to them, and that needs to change," she said. "In the same way that we need to innovate and transform our real economy, we also need finance to change and innovate."

Olago called for more climate-led investing—deploying capital in a way that provides economic opportunity without mortgaging our future. "To get to net zero by 2050, we have to halve global CO_2 emissions by 2030, just eight years away," she pointed out. "That means transforming how we build things, how we power things, how we move things around globally. The UN estimates we need another three to four trillion dollars every year."

It's not just lack of money, it's where it's being invested. Most climate finance flows into related software, like climate risk insurance, or technology that has been tried many times and feels safe for investors—onshore wind for renewables, for example. The level of investment needed to decarbonize steel—responsible for seven percent of global emissions—is too large for venture capital, and the industry is too asset-heavy for growth equity.

"Climate-led investing seeks to overcome this by capitalizing climate impact at scale, while still delivering risk adjusted returns," she told the room. "And that second piece is important, because addressing the climate challenge will need a lot of institutional-grade capital."

Olago spent her childhood in both Kenya and Ukraine, "both places where, to have economic opportunity in the present, means you cannibalize the future—with consequences further down the line," she pointed out. "Climate-led investing should focus on deploying capital for economic opportunity with longevity—ours, as well as the climate's."

She heads up investor relations and fundraising for Just Climate—part of Al Gore's sustainable hedge fund Generation Investment Management. Just Climate invests globally across energy, transport, industry, and buildings, as well as natural climate solutions, food, agriculture, and oceans.

Her role is partnering with institutional investors such as pension funds, insurance companies, and family officers—"People who are the hardest to convince to do something new," she smiled—to guide investment into the highest emitting, hardest to decarbonize sectors, decarbonizing energy, green steel, and cement, while backing renewables.

The good news is that they've had enough success to develop a proof of concept for climate investing. However, they need to increase the capital flow by almost 10 times, and ensure it goes to the right places: "We have a very narrow window in which we can act."



Evelina Olago,
client director, Just Climate

THE CASE FOR CLIMATE-LED INVESTING

Now is the time to steer influential institutional investors toward funding climate-crisis solutions at scale

The technology that will carry humanity toward a sustainable future is already here, said Greg Jackson, CEO of Octopus Energy, but heavy-handed regulators and outdated infrastructure are standing in the way of progress. The key to addressing the problem, he suggests, is to take a lesson from the history books.

At WIRED Impact, Jackson asked the audience to imagine a scenario in which the early innovators of the internet era—figures like Tim Berners-Lee, creator of the World Wide Web—were not given the freedom to experiment. The ramifications for the pace of development would have been severe, he explained, and yet "this is the reality for renewable energy today."

To illustrate the gravity of the problem, Jackson pointed to the obstacles faced by sustainable energy projects in the United Kingdom. Although constructing a wind energy facility takes only two to six months, connecting a new farm to the grid can take seven years, due to the abundance of red tape—a situation Jackson described as "disastrous." "We're talking about a revolution that's probably more important than the internet, one that will save our planet," he said. "But it's being held back by the enormous amounts of central planning."

The issue, Jackson claimed, is partly that regulators do not understand the degree of change that is required to meet climate targets (the UK has pledged to reduce greenhouse gas emissions to net zero by 2050). This means that those at the forefront of renewable energy development have not been given the freedom to explore all available options.



Greg Jackson, CEO, Octopus Energy Group

Bureaucracy can't be allowed to hinder transforming the energy sector, says Greg Jackson.

Jackson said it's a mistake to wait around for "hit and hope" solutions like nuclear fusion or carbon sequestration as a route to meeting emissions targets, particularly when there are effective steps that can be taken now.

The fact that renewable energy generation is subject to the whims of the weather does pose difficulties, he conceded, and patterns of energy consumption will need to change accordingly. But Jackson added that technology is available that would allow the UK to move to an intelligent, automated system that makes it easy for people to tap into cheap green energy when supply is plentiful, and minimize their usage when it's not.

This kind of system would create opportunities in a commercial context too, in fields like vertical farming, whereby crops are grown indoors and in close proximity to large population centers. The combination of plentiful renewable power and flexible energy tariffs, said Jackson, would allow farmers to light and heat their crops only when it's windy or sunny, cutting the costs and emissions associated with food production and transport.

However, the problem is not only that bureaucracy is slowing the development of new renewable energy facilities, but also the limitations of the UK's power infrastructure. Because the grid was designed for an era when only a few power plants produced the majority of energy, and not for a setup whereby generation is widely distributed, the UK has to throw away hundreds of millions of pounds worth of "carbon-free electrons" each year: "We don't have the cables to transport it."

Jackson added that this state of affairs is particularly galling in the context of the current energy crisis, which has served to emphasize the urgent need for investment in modernizing the country's power infrastructure.

It is clear the UK power grid is "broadly not fit for purpose—neither the infrastructure nor governance," he said. "We need to give access to the market to all technologies that are going to transform energy." **Joel Khalili**

GREEN ENERGY WILL BE BIGGER THAN THE INTERNET

We have a huge opportunity to unshackle ourselves from fossil fuel-derived energy, if infrastructure and legislation can keep up

**Arnavaz Schatten,
director of sustainability, InFarm**

SOWING THE SEEDS FOR A BETTER FOOD SYSTEM

Vertical farming could reduce the environmental impact of food production—if it can move to the center of the plate

Growing wheat indoors could transform its environmental footprint—if the energy-use factor can be solved.

If you've watched *The Martian*, you'll know how difficult it is to grow food on Mars. Almost nothing about the Red Planet makes it a hospitable place for agriculture. Even if you could coax a plant to emerge out of the nutrient-bereft soil, it's just a matter of time before the sproutlings succumb to either the freezing temperatures or a total lack of accessible water.

Mark Watney—played by Matt Damon in the film—stays alive by eating potatoes grown in an airtight dome and fertilized with his own poop.

Watney's experiment has a lot in common with vertical farming. Not the human poop so much, but the idea of growing plants in a way that's utterly disconnected from their surrounding environments. "What could possibly work on Mars could be hugely beneficial on Earth today. We don't need to wait for the Mars scenario. We need this kind of farming on Earth now," said Arnavaz Schatten, director of sustainability at the Berlin-based vertical farming firm InFarm, when speaking at WIRED Impact. In vertical farms, plants are grown without soil under artificial lights in a setup that uses much less water, soil, and pesticides than conventional agriculture. Detach the plants from their environment and we can massively reduce the environmental impact of our food system. (Which, by the way, is huge.)

That's the theory, at least. In reality, the impact of vertical farming is totally dependent on the kind of crop we're talking about. Right now, InFarm mostly grows herbs, leafy greens, and salad vegetables. These are a good starting point for vertical farms because they're fast growing and command high prices, but they make up a vanishingly small proportion of the food grown in the world. Next on InFarm's shopping list are strawberries and mushrooms, but the real impact will come from making staple crops like wheat, soy, and maize more efficient. Just a small handful of crops take up the vast majority of farmland and resources. Bring those crops indoors and we'd really start to make a dent in agriculture's huge environmental footprint.

That is exactly what the company has started doing. In November 2022, InFarm announced that it had grown wheat in an indoor farm for the first time, without using soil or chemical pesticides. If this test system was recreated at scale, the approach could produce 26 times more wheat per hectare than conventional open-field farming. But that doesn't mean that open fields are going to be replaced by warehouses crammed with wheat plants any time soon. Indoor farms have vast energy bills, and if they're located in urban areas, labor and land costs are much higher than conventional agriculture, too. Proponents of vertical farming hope that increased automation and renewable-powered energy supplies will drive down those costs and make it feasible for commodity crops to be grown indoors at scale for the first time.

"If you're serious about solving the world's food system challenges, we need to think in terms of calories," says Schatten. "Vertical farming needs to move from the edge of the plate, further towards the center of the plate." **Matt Reynolds**





Gaia Vince, author, Nomad Century

MIGRATION ISN'T THE PROBLEM, IT'S THE SOLUTION

If planned for properly, climate migration need not be a source of conflict, but rather of opportunity

Climate migration is already underway—four times as many people are displaced by extreme weather as conflict, author Gaia Vince told the room. "The four horsemen of the Anthropocene—heat, drought, fire, and floods—mean large parts of the world are increasingly going to become unlivable, and as many as 1.5 billion people will need to move." Planned migration has many benefits, she argued, offering the quickest route out of poverty for people forced to move, and making it easier for rich host nations to increase their labor pool and GDP.

Helping refugees can be a good way to foster innovation, Hovig Etyemezian, head of innovation at UNHCR, added. With impact entrepreneur Innocent Tshilombo, who fled violence in the Democratic Republic of the Congo to the Kakuma refugee camp and founded Kakuma Ventures to help refugees become entrepreneurs, they developed solar-powered Wi-Fi for African refugee camps, and raised digital literacy to allow people to get online. "Every day we have to solve problems on the spot," Etyemezian explained. The results create sci-fi tech such as eye-scan ATMs in the field, but also restores agency to people who feel powerless.

WIRED Impact.



Lubomila Jordanova, CEO & cofounder, Plan A

BUSINESSES NEED TO GET REAL ABOUT THEIR CARBON ACCOUNTING

Without proper auditing, it will be impossible for companies to decarbonize effectively

We can't stop climate change until companies can measure and understand the bottom line cost of environmental harm, according to Lubomila Jordanova, CEO and cofounder of Plan A, a Berlin-based company developing an AI software platform for decarbonizing corporates. Companies ignore the cost of pollution, she explained, because it's hard to measure. She's signed up over 1,000 companies to collect data across their supply chain and over time. They get a true, costed picture of their economic growth if they don't change—typically cutting projections from seven per cent to as little as one or two per cent—and help in spotting ways to improve. One problem is greenwashing—creative climate accounting that presents an artificially benign picture. "I have been amazed at the creativity that companies employ," she shook her head in despair. "But a lot of greenwashing isn't conspiracy, it's ignorance." Because of the low level of education in the market for customers and companies alike, Jordanova explained, some companies might think they're doing the right thing, even if they're not.



Uğur Şahin, CEO, BioNTech

PUBLIC HEALTH MEETS CLIMATE JUSTICE

We shouldn't sacrifice net-zero goals in the race to bring healthcare equity to everyone

Covid vaccine technology will soon deliver cancer, malaria, and tuberculosis vaccines from shipping-container vaccine factories in developing countries, said BioNTech cofounder professor Uğur Sahin. His plan is to help improve the world's health without increasing its carbon footprint. Sahin and his partner Özlem Türeci, whose mRNA platform provided the Pfizer jab, are developing small, solar-powered energy-neutral factories to overcome the energy needs and carbon produced when flying vaccines around the planet, sometimes at -80°C. "The idea is to have 20 of these modules worldwide, he explained. "Every time a new vaccine is developed, the processes could be submitted by data, and people who are trained to use what we're calling a BioNTainer can just start to manufacture the new vaccine." Data gathered over the pandemic has illustrated the public health problems caused by environmental factors, he told the room. "Carbon neutral factories producing vaccines locally means we can react faster and minimize waste."

Hayaatun Sillem and Lila Ibrahim argue that inclusion is a non-negotiable for making progress.

IMPACT BRIEFING

ENSURING A DIVERSITY OF VOICES WILL HELP TO SOLVE THE HARDEST CHALLENGES

Workforces that champion inclusion and underrepresented groups isn't just a corporate flex—it's the key to innovation

Lila Ibrahim,
COO, DeepMind

Hayaatun Sillem,
CEO, Royal Academy of Engineering

Engineering has a white-male problem. Women make up just 14.5 percent of the engineering workforce in the United Kingdom, with ethnic minorities constituting just 8 percent.

For Lila Ibrahim, chief operating officer at DeepMind, and Hayaatun Sillem, CEO of the Royal Academy of Engineering, being both female and people of color meant the odds were stacked against them in their industry.

But for Sillem, who is the first woman and ethnic minority to hold her position, coming from such a diverse background helped her "to build empathy into her life"—a trait she describes as a superpower. She has found that she's happiest when being an outsider on the inside, and trying to create those connections between the insiders and the outsiders.

And as for Ibrahim, the daughter of immigrants to the United States, she always felt like the "oddball" growing up in midwestern America, with English as her second language. "What that has meant throughout my career is that there's been doors opened to me that others might not embrace, because I can see things from a slightly different perspective," she told the room.

Sillem's extra visibility in her role as an underrepresented minority has meant that she could raise awareness and address the lack of diversity faster. "The fact is that by just doing this job, I can make more change happen, just by virtue of what I look like," she says. There's a flipside to that too, of course, Sillem says: people from underrepresented backgrounds are often looked at as the ones to "fix" diversity and inclusion challenges within an organization, but in a good organization, that shouldn't happen. For Ibrahim, she sees her role now as finding great people and giving them the empowerment to succeed—and the space to fail.

Having diversity and inclusion as a priority produces tangible positive impacts. Ibrahim cites the example of DeepMind, which when pioneering its groundbreaking protein-folding AI system, AlphaFold, kept equitable access front of mind. One way the team did this was by working with a neglected disease initiative to focus the tech on discovering new treatments for two parasitic diseases that affect the Global South but which



Western industries tended to ignore. With the help of the AlphaFold technology, the initiative was able to speed up the development of a new drug to treat one of the diseases. When it comes to achieving the long-term goals of science—benefiting humanity, ultimately—having diverse voices is critical, Ibrahim says, "because you have more people around the table that represent what the world looks like."

For addressing the most pressing issues the world faces today, diversity and inclusion are a non-negotiable. "It's a necessary condition for making progress on the things that affect the future of humanity," says Sillem. "Unless we have a more inclusive approach to the global innovation community, we will not create resilient, effective responses to those massive shared societal challenges." But, she warns, the job is never done; there will always be more work to do. "Diversity is not an end-state you're going to get to—so you have to enjoy the journey." **Grace Browne**



Alyssa Gilbert, director of policy, Grantham Institute, Imperial College London

Citizens can make a positive impact on policy, if they speak out in a coordinated way.

MAKING BETTER CLIMATE POLICY

People power can influence regulations for the better

To stop climate change, the best thing you can do is speak up, said Alyssa Gilbert, director of policy at the Grantham Institute at Imperial College. Policy makers and businesses are stuck in a deadlock—but if citizens apply pressure, they can be forced to change.

"Existing policies on climate change have prevented emissions, which is great—but nowhere near enough," she told the room. "There's regulation standards, market mechanisms and innovation R&D, and a whole load of supporting structures. There are a range of different policy instruments that can be useful, and we need to be better on policy than we have before."

The problem, she explained, was that most people care about the issue, but citizens felt they couldn't make an individual difference, while business people want policy guidance, and politicians won't act in case citizens won't vote for them again. "We need a coordinated set of activities, so each group is bold enough to take a step in the right direction, and then they all move together," she argued.

The easiest way for everyone to counter the lobbying pressure of fossil-fuel-based companies is to put counter-pressure on their politicians.

"It makes a difference if you write to your MP, councilor or representative," she explained. "Not many people take the time to write, so they really listen when you do."



Leonie Mueck, chief product officer, Riverlane

New methods for cubitization of data will transform quantum's uses.

SCALING QUANTUM COMPUTING FOR CLIMATE INNOVATION

The technology will be key to creating innovations in climate-related materials science

In 10 years' time we could have quantum computers accurate enough to accelerate innovation in material science and chemistry in the battle against climate change, Leonie Mueck, chief product officer for quantum software startup Riverlane, told the room.

A chemist by training, Mueck recalled trying to get an organic chemical reaction to work in the lab. "I tried to vary everything—temperature, catalyst, solvent, nothing worked," she said. She wished for a computer able to simulate the activity in her flask so she could model the solvent or catalyst and ensure her reaction worked.

Her problem? Electrons in a reaction behave according to the rules of quantum mechanics and defy classical computing. Quantum computers, she pointed out, are ideal for this. They can help design better batteries, improve industrial processes, create more effective drugs, and unlock innovation in a vast variety of topics connected to climate change.

Unfortunately, Mueck explained, the quantum level qubits at the heart of the machine create unavoidable errors, thanks to Heisenberg's uncertainty principle.

To correct these errors, quantum computers need to process the equivalent of Netflix's worldwide data rate every second.

One new way of mapping chemical problems onto a quantum computer—called qubitization—brought the run-time for calculations on solar-panel chemistry down from hundreds of thousands of days to just a couple of days, she explained.

It needs to fall further, but Riverlane and Google have hit their first milestone in achieving that, so the signs are good.



Kim Stanley Robinson, science fiction author, Ministry for the Future

HOW SCI-FI CAN HELP US RECOGNIZE —AND DETERMINE— OUR NEAR FUTURE

Fiction can help us explore potential ways to mitigate the worst impacts of climate change—and even help us build a utopia

We need an exit ramp for petro-states to stop climate change—and there isn't one, author Kim Stanley Robinson warned the room. "They'll need compensation, because their national priorities are intensely tied up with these fossil fuels, and there's two billion people in those states," he explained. "We're going to have to pay them to keep it in the ground."

In his best-selling novel *Ministry for the Future*, Stanley Robinson proposes what he calls carbon quantitative easing—compensating countries for keeping oil in the ground. It would involve trillions of dollars which, he admitted ruefully, would "have to be dispersed to kleptocracies and the people involved just to keep the world alive. There's nothing gnarlier than this part of the problem."

Ministry for the Future is a deeply researched take on the next few decades, using hard atmospheric science and oceanic physics to imagine the eponymous new climate crisis body trying to geoengineer the saving of the world.

In the aftermath of a horrific heat wave that kills 20 million people in India, the Ministry sponsors technological tricks to slow warming, while its leader, Mary Murphy, confronts central bankers in a bid to break petro-billionaires and shift the economy away from fossil fuels. Robinson transforms our existential crisis into a story of resilience and redemption.

Kim Stanley Robinson explains to the audience how climate has become a global conversation that we're all having.

The role of science fiction is to support utopias, Stanley Robinson suggested. "I wanted to create a plausible best-case scenario you can believe in. We need to dodge mass extinction and keep civilization healthy. *Ministry* serves as a spark—this sounds possible, let's pursue it."

He has no time for extremes of protest, he added. "Rule of law, as weak a reed as it is, is all we have. If virtuous eco-warriors were to seize power and enforce a virtuous action, that wouldn't work."

He also supports geo-engineering—"you put dust in the atmosphere and five years later it's gone. It's an experiment that won't go awry and kill the world"—because he thinks nothing should be off the table in an emergency.

People's hunger for optimism has driven book sales that surprise even him, he smiled. "Something big has been happening since the pandemic—climate change is on the brunt of discussions. Even the Ukrainian war is discussed in the context of clean energy. It's the overriding story of our time."

He believes the concept we have to leave behind is the idea of the nation state, which he dismissed as a 17th century idea. "We are all member states of the Paris Agreement. We are citizens of the world. And we're all in a science fiction novel that we're co-authoring together. We want it to be utopian, but it looks dystopian right now. There's a genre clash, and we have to fix that problem."

Ellen Moeller of carbon accounting platform Watershed, says businesses need to decarbonize urgently.

Could accountancy stop climate change? Ellen Moeller, head of Europe at carbon accounting platform Watershed, told the room that the company's goal to remove 500+ megatons of CO_2 from the world's atmosphere annually needed forensic auditing, aggressive reduction, and investment in carbon capture or removal—but "that path to 1.5 degrees Celsius is looking more and more uncertain."

To hit the target in practical terms, she explained, "we need to reduce emissions by 50 gigatons by 2050, and we need to be halfway there by 2030. That's a big task, we are not on track, and this is the credible decade to do it."

The two key levers, she told the crowd, are reducing emissions and removing carbon from the atmosphere. "Listed companies alone, they've got about 40 percent of climate warming emissions, and so they're going to have a huge impact," she pointed out.

Businesses release carbon into the atmosphere directly—running vehicles or heavy industry—and through buying electricity from the grid. This grid carbon, known as "scope three", is usually the largest part of a company's carbon impact—especially in the tech sector—and is extremely hard to measure. But impending regulation means companies need to get started, she said.

The US Securities and Exchange Commission is preparing to require firms to report scope-three emissions, while the EU has issued rules that will make nearly 50,000 firms subject to reporting requirements.

For companies like Stripe, Spotify, Klarna, and Airbnb, Watershed acts like a carbon bookkeeper, taking data from electricity bills and company travel systems through supplier line items on the books, and creates a granular carbon footprint. The company, founded in 2019, helps organizations change—from the hardware they buy to how they build their HQs.

"We work with them in three areas: To source clean energy, increase land use efficiency, and engage with suppliers to find less carbon-intensive options," she said.

Watershed also offers customers access to carbon removal via a dashboard marketplace that focuses on "frontier" carbon removal by working with start-ups such as Carbon Engineering, which sucks carbon from the air; Charm, which uses plants to soak up CO_2 and then converts them into liquid biomass, which can then be pumped into the ground; Running Tide, which is creating islands of CO_2-gobbling kelp; and Heirloom, which captures CO_2 in prepared limestone.

It's not just a moral choice—it's also good business, she argued. "Reducing your logistics footprint can have meaningful financial benefits and give you a competitive advantage with companies looking for suppliers who have a credible path to decarbonization."

Investors are thinking about this too, she pointed out—citing Just Climate's client director Evelina Olago's talk on climate-led investing earlier in the day. "The collective effort is what really makes the difference."

Ellen Moeller,
head of Europe, Watershed



DATA-LED CARBON-CUTTING

Businesses are responsible for the bulk of carbon emissions. They need a smart audit of their outputs, and a credible plan

Mapping the future of healthcare

WIRED Health explores what's coming next for healthcare, examining the big ideas, academic breakthroughs, innovators and disruptors transforming how we access, provide and improve patient care.



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EY

SMALL WONDERS

Edited by Jeremy White Photography Mitch Payne Words Chris Haslam

Good things come in little packages, so WIRED decided to celebrate our favorite tiny tech by super-sizing it to reflect its outsize impact



Positive Grid Spark MINI ▲
WIRED was a Spark amp fan even before Positive Grid brought out this, its smallest speaker. Just 146.5 x 123 x 165 mm, this 10-Watt Class D amp is, amazingly, full stereo, the rechargeable battery is good for eight hours, and the MINI will even double as a superb Bluetooth speaker. *£169 positivegrid.com*

Bruder Dumper ▲
German firm Bruder is renowned for lavishing authentic detailing on its lifelike 1:16-scale vehicles—but this one isn't actually based on a real truck. Designed for kids from 2 years, the emphasis is on a tough build, but it won't look out of place when they graduate to the Bruder Pro line. *€32.95 bruder.de*

Fiido X Electric Folding Bike ▼
Available in 250W (15.5 mph) and 350W (19.2 mph) options—the legality of which depends on your location—with a 417.6Wh battery disguised as a removable seat-post, this folding e-bike is a mini marvel, concertinaing down to a mere 79.4 x 35 x 80.3 cm, but giving a reported 130 km of electrical pedal assistance. There's keypad-lock security for the battery, a seven-speed Shimano gear set, and a torque sensor that adjusts how much help you get, depending on how hard you pedal. *£1,491 fiido.com*





The Palmer ▲
Elegantly simple, keychain-friendly, and decidedly useful, the anodized aluminum and steel James Brand Palmer pocket knife is a must-have, if, like WIRED's Gear editor, you open more cardboard boxes than most. Featuring a classic safety-knife-style cutter that's perfect for piercing and slicing, the mechanism is silky smooth, locks safely, and the blade can be replaced without the need for tools. Available in six colors, it measures 8.8 cm long, and weighs just 76 grams. *£59 thejamesbrand.com*

Oris Coulson Limited Edition ▼
The innovative case of this watch is a collaboration between Oris and Zurich's Swiss Federal Institute of Technology, combining 3D-printed layers of carbon fiber and PEKK—an aerospace-grade polymer. As a result, this 41 mm watch weighs a mere 65 grams. The striking "flame" dial signifies this limited edition is also a partnership with Coulson Aviation, a Canada-based aerial firefighting outfit. Power is supplied by Oris's new -3/+5 seconds per day Calibre 400, with a five-day power reserve and 100-meter water resistance. *£3,400 oris.ch*



Bworld Lifeguard Station ▼
Bruder isn't just combine-harvesters and giant dump trucks—this bumper set takes to the beach, comprising a *Baywatch*-style lookout station with an office and a flashing warning light, plus a quad bike, jet ski, and a lifeguard to stand around and judge the sunbathers. *€60.95 bruder.de*

Rogue-Lite X ▼
Measuring just 30 x 30 cm when rolled, and weighing a mere 4.7 kg, the Rogue Lite X makes it easy to take a boat with you wherever you go. Unlike many cheaper, flimsier options, this one has Kevlar on the floor and sidewalls, making it tough enough to tackle beachings on rough ground and unexpected flotsam. Once blown up using the supplied inflation bag, it measures 216 x 94 cm, can carry up to 136 kg, and is more fun to paddle than it has any right to be. *$1,099 kokopelli.com*





NOCS Monolith Speaker ▲
This 12 kg, 550 x 380 x 180 mm, block of audio minimalism features five drivers and inky birch ply casing. The drivers are engineered and made in Denmark by Scan-Speak, and the whole package is hand assembled in Sweden—a modular design allows for future upgrades and repairs. There's two 6-inch woofers and three full-range 3.5-inch drivers powered by a 150W Class-D amp, plus Bluetooth 5.0, Wi-Fi, Spotify Connect, Tidal Connect and Apple AirPlay 2, and you can even link *eight* of them together. *£1,290 nocsdesign.com*

Mercedes-Benz UPS Sprinter Van ▲
The included UPS personnel can use the loader to fill up this delivery stalwart via the rear doors, or grab smaller packages through the side entry. Thrillingly, the miniature pallets are accurate scale reproductions of the standardized 1,200 x 800 mm Euro Pallet used across the continent. Details! *€58.95 bruder.de*

Land Rover Defender with Trailer ▼
Resplendent in green, this model captures the uncompromising blocky practicality of the real Defender, right down to the diamond-tread kickplate at the door edges—it's just begging to be sploshed through some muddy puddles. Besides the trailer and a driver, the set also comes with a mini JCB excavator to tow around, so there's really no chance of ever keeping it clean—but frankly, why would you even want to? *€33.95 bruder.de*





JBL Go 3 & Clip 4 ▲

JBL's latest bargain Clip Bluetooth speaker builds on the positives of its three predecessors: About the size of a hockey puck, it's IP67-rated water- and dust-proof, weighs just 239 grams, and has a supremely handy (and this time, sturdier) carabiner clip, so you can snap it to whatever outdoor gear you choose, then head off into the unknown. A single charge will give you 10 hours of playback of surprisingly good quality. The Go 3, on the other hand, is even cheaper, smaller, and lighter, yet still IP67-rated. The trade-off? Only 5 hours of playback. *£33, £40 uk.jbl.com*

Bowers & Wilkins Px8 McLaren ▶

The B&W Px7 S2 were among our favorite over-ear headphones of 2022, but they've been quickly surpassed by the new flagship Px8, with their carbon-fiber and resin drivers, luxurious choice of materials, stellar active noise cancellation, and sublime audio performance. They're a premium pick on every level, but we can't help lusting after this F1-inspired McLaren collaboration, with their trademark Papaya Orange accents. No, the subtle branding and achingly cool flashes of color are not worth the £100 price bump, but once you're ready to head north of £500 for headphones, we suggest you listen to your heart and ears, rather than your head. *£699 bowerswilkins.com*



John Deere 7R 350 with Frontloader ▲

You can't say "tractor" without thinking "John Deere"—and Bruder is happy to supply multiple models as part of its humongous farming range. Besides scooping and hefting fun, it's steerable—if you can't get your fingers into the cab, an extender bar attaches to the steering wheel and pops out through the roof. *€49.95 bruder.de*



Quip Smart Rechargeable ▲
The original subscription-based Quip toothbrush had one major flaw: It ran using AAA batteries. This has been rectified in some style, with the latest design having a built-in rechargeable battery that lasts up to three months on a single charge. And, while maintaining its sleek and portable proportions, it can now also go tooth-to-tooth with the big boys via its own Bluetooth-synching companion app featuring auto-tracking and a money-saving rewards program, plus vibration timers and reminder alerts to maximize your dental hygiene. *$60 getquip.com*



Audio Technica Sound Burger ▲
This portable, battery-powered turntable is pure 80s nostalgia—and thankfully, Audio Technica has given this reissue an upgrade with Bluetooth, a USB-C port for charging, and an RCA audio cable to connect it to a proper speaker. But most significant is the fact that, despite the outwardly kitsch design, it's bundled with a perfectly good (and replaceable) ATN3600L stylus that won't chew up your vinyl. *£199 audio-technica.com*



Nebula Capsule 3 Laser ◀
This 950-gram, 17-cm-tall soda-can projector throws a bright 1920 x 1080p, 120-inch display (300 ISO Lumen) from just 3.5 meters for up to 2.5 hours. There's also auto-focus and ±40° auto-keystone correction, loud and detailed 8W Dolby Audio speakers, HDMI 2.1, and Chromecast built in. *£799 seenebula.com*

Linde H30D Forklift ◀
The real-size Linde forklift was designed by Porsche Engineering, and the 1:16 version shares its clean lines and signature red hue. You can whizz this one around your "warehouse" via a steering column. *€20.95 bruder.de*

Raleigh Tuff Burner ▼
Readers of a certain vintage will be misty-eyed at the return of the Tuff Burner—the bike that ruled playgrounds in 1982. Raleigh has recreated its iconic stunt-steed as a 40th-anniversary edition that channels all the flair of the original. Yellow Skyway 20-inch Tuff rims? Check. Blue gum-wall Snake Belly tires? Check. Kashimax Areo saddle, snap-on bar pads, and two-tone Kraton grips? Check! Check! Check! And the best part? The frame geometry has been tweaked to make sure it can safely take "bigger kids" who fancy a bunny-hop. *£600 raleigh.com*

Bworld Bike Shop ▼
Hipsters rejoice—you can finally own your dream cycle shop. This set has bikes to strip and rebuild, a workshop with tools and spares, a till, and wall panels in bare concrete or edgy graffiti. The only thing it doesn't have is an espresso machine … *€33.95 bruder.de*



YNIQ Lindsey Vonn ▼
These Swedish designed, Italian-made ski goggles boast "peripheral vision technology": Built into the self-supporting powder-injected stainless-steel rims you'll find two small side-windows that offer up the widest possible view. Helmet-compatible, they're supplied with two magnetic lenses for quick and simple swaps: One a gold mirror on a pink base for enhanced visibility in challenging light, the other a blue smoke mirror lens for bluebird days. *€700 yniq.se*





Hyperlite Headwall 55 Skiing Backpack ▲
Hyperlite's new Headwall 55-liter Ski Pack weighs in at under 1.2 kg, thanks to being constructed from abrasion-resistant Dyneema, which is 30 percent lighter than nylon and polyester, yet 15x stronger than steel (on a weight per weight ratio). Designed with help from pro skier Cody Townsend, the Headwall 55's party trick is that it can carry skis, snowboards, or split boards, thanks to specially reinforced side panels. *$449 hyperlitemountaingear.com*

Oakley MOD7 ▼
This all-in-one helmet and visor combo does away with any fit or adjustability issues typically experienced by goggle wearers. The Prizm lens is connected to the advanced polycarbonate MIPS (Multi-Directional Impact Protection System) helmet via strong magnets, meaning there's no cold spots and no risk of losing your goggles if you take an unexpected headplant in the snow. Eject buttons let you swiftly swap lenses to match conditions. *£404 oakley.com*





Velo Expandable Suitcase ▲
By pressing the buttons on the top of the handle, you can expand or contract Velo's case between a 16-inch compact, 22-inch business class carry-on, or a larger, stowable 26-inch design for longer excursions (or when you've gone overboard on the souvenirs). Made using a water-resistant polycarbonate shell and aluminum frame, the mechanism has been tested a reported 3,200 times, while the packing cubes ensure your gear remains organized. *$249 veloluggage.com*



Prinoth Leitwolf Snow Groomer ▲
Avid skiers will know it takes a hardy machine like the Leitwolf to primp snow to perfection. This impressive toy features chain treads, an adjustable front plow-blade, and a rotating tiller at the back to create slopes worthy of Vail or Val d'Isère. *€91.95 bruder.de*

Nidecker Supermatic Snowboard Binding ▲
With universal compatibility and exceptional adjustability, riders can use the Supermatic as a standard ratcheted binding, or deploy the speedier Drop-In technology. By pulling the highback plate away, the main strap is pushed forward, allowing plenty of room to slide your boot inside. Plus, it's still as responsive and adjustable as a classic binding. *£365 nidecker.com*

LifeStraw Community ▲
The LifeStraw Community is a jumbo filter designed to offer 70,000 to 100,000 liters of purified drinking water, equivalent to serving 75 people for up to five years. Through its Give Back program, LifeStraw will donate, install, and maintain one in a Kenyan school for every 500 products it sells. To date, 2,225 schools benefit from the scheme. *$395 lifestraw.com*

Mack Granite Fire Engine ▲
For 20+ years, Mack Granite trucks have performed all sorts of heavy-duty hauling, including fire-fighting. This huge model has a working water pump and hose, while the cab bristles with authentic details, such as the adjustable stabilizer legs. *€109.95 bruder.de*

Eastpak Lunch Yellow ▼

Eastpak's already colorful range of tough polyester bags and accessories has leveled up with a Super Mario collab which splatters coins and characters across everything from hold luggage to pencil cases—but the standout has to be the 18 x 18 x 18 cm Question Mark Block food carrier. Insulated and lined with reflective material, it will keep mushrooms, double-cherries, and blimp fruits (or, you know, just your sandwiches) cool and fresh. It's-a-lunch-time! *£37 eastpak.com*



John Deere 1270G Harvester ▼
Forests beware: This 8-wheel variant of John Deere's harvester is here to rip you up by the roots (and, yes, plastic topiary is included). Fortunately for aspiring tree-huggers, you can easily swap out the harvester unit for a hook, as the vehicle's improved stability also makes this great fun to use as a crane and loader. *€74.95 bruder.de*



Namuk Eon 14L ▲
Namuk uses grown-up tech to make high-performance gear for kids, and the Eon backpack exemplifies this with a waterproof (3,000 mm Hydrostatic Head), fully-taped, roll-top design made using polyester and nylon textile fibers that are up to 15 times stronger than steel. The inner lining can be used as a seat pad, and the drawcords are reflective for low-light visibility. This bag is sized for people between 3 and 8 years, but fear not, jealous adults—a scaled-up version is coming this year. *$99 namuk.com*



Anker PowerHouse 767 ▲
A worthy investment for serious van-lifers, Anker's PowerHouse kicks out 2,300 Watts (2,043Wh) of power on the go for up to 10 devices, via 10 ports, with rapid recharging to 80 percent in just one hour, and the possibility of taking 1,000W of charge from compatible solar panels. Tough, expandable, and tested for 3,000 charge cycles, it also features the GaNPrime chip which enables the batteries to operate at cooler temperatures for longer-lasting power in all conditions. *£2,399 anker.com*



BioLite Solar Panel 100 ▲
These foldable solar cells feature an ETFE laminated surface to protect them from damage. A single unit can output up to 100W into your devices via USB-A and USB-C ports, or be plugged into a power bank (the Anker model requires an HPP to XT-60 port adapter) to store it for later. Four panels can be chained together to offer 400W, and the adjustable kickstand and integrated sundial ensures the cells are positioned for maximum solar gain. *$399 bioliteenergy.com*



Insta360 X3 ▲
Shoot first, edit later, with a 5.7K Active HDR 360° action cam that also records to depths of 10 meters. Then, pick your angles via touchscreen or app for videos, 72MP photos, 8K timelapse, and first-person 4K 30fps clips. "Extreme" meetings are also an option, with a Conference Webcam mode. *£459 insta360.com*

DHL Store ▲
You're never too young to explore career options, and logistics-minded kids will love scheduling shipments and collections from this tiny DHL outlet. There's a lifter, a checkout and parcel scale, plus a backdrop that flips between pickup lockers and a store. We feel more organized already! *€25.95 bruder.de*



Atech 10-in-1 AirTag Tool ▲
Compact multi-tools are a godsend—providing you can find yours when you really need it. Atech's 10-in-1 is 34 grams of hard-wearing, hard-working keychain functionality, with the added bonus of an Apple AirTag slot for forgetful fixers. An ideal bike tool, it features a 3.5/4 mm spoke wrench, a 4 mm hex wrench, a 1/4H hex wrench, a 5.5/8/10/12 mm hex wrench, Phillips driver, flathead driver, bottle opener, and a fold-out stand allowing you to safely prop up your phone and watch "How to fix my ..." videos on YouTube. *$39 atech.com*

Timeore C3 Max Pro ▼
Give your hand-roasted Liberica beans the love they deserve with this portable conical burr grinder made with the most discerning of baristas in mind. The 660 stainless-steel grinder is milled using the latest 6-axis CNC machine for ultimate precision, while the 52-mm-diameter aluminum body has capacity for 30/35 grams of beans. Add to that a tactile anti-slip texture on the body, plus a spring-assisted fold-down handle for smooth grinding, and you've got the most gorgeous go-anywhere grinder. Just don't forget the scales. *$109 timeore.com*



Volvo Hauler A60H ▼

The descendant of the 1966 "Gravel Charlie" dump truck, Volvo's hulking 55,000 kg A60H hauler is the largest of its kind, and makes for an impressively chunky toy. Like the real thing, this one also has articulated steering and huge balloon tires, so it can handle even the roughest worksite/back garden. *€81.95 bruder.de*



Palladium + Finisterre Pallatrooper Hiker WP+ ▲

The Pallatrooper Hiker WP+ continues an unblemished record of collaborations between Cornish outwear brand Finisterre and French shoemakers Palladium. An ultra-rugged, unisex, waterproof walking boot, its Sympatex membrane and a special coating on the polyurethane (PU) upper provide thorough water resistance, while recycled rubber mudguards and a recycled rubber bottom (along with that recycled PU top) round out this hard-working shoe's eco credentials. *£170 finisterre.com*

Bruder Pro Series Toys

Bruder has been in the toy biz since 1958, and is renowned for its highly-accurate vehicles, which are rich with detail, even at 1:16 scale. Yes, you may well wonder what sort of child dreams of owning a lifelike model DHL parcel shop or a *very specific* type of garbage recycling truck (Mack, Scania and MAN varieties are all available, BTW), but if intricate, somewhat sensible world-building is your thing, Bruder can supply a super-realistic model that's a serious cut above Playmobil or Hotwheels. *bruder.de*

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ARTWORK BY FROMM STUDIO



“PPM IS NOT A TOUGH GUY.”

PEDRO PASCAL CARES ABOUT YOU.

HE’S ALSO SELF-CONSCIOUS ABOUT CARING ABOUT YOU.

THIS IS EXACTLY WHAT MAKES HIM GREAT.

BY HEMAL JHAVERI | PHOTOGRAPHS BY PETER YANG





PEDRO PASCAL is a little *too* nice, actually. Too many hugs. So many polite refusals of snacks. On the set of a photo shoot for this interview, there's an evident tension inside him. He retreats into the aloofness of celebrity, but he is also eager to connect. He seems to enjoy having his picture taken, but he gets shy when the photographer moves in for a close-up. It's in his nature to be open, but he holds a lot of himself back. He's not too far off, in fact, from the anonymous bounty hunter he plays in *The Mandalorian*. He wants to take off the mask and let people see his face, but he doesn't want to deal with the fallout.

Too bad. Not only is Pascal returning for season three of *The Mandalorian*, he's also starring in HBO's *The Last of Us*, probably the biggest video-game-to-TV adaptation of all time. In that now oh-so-recognizable face of his, one senses, well, shock. It's unthinkable—magazine covers, TV stardom, all of it—for a kid who wrapped himself up in '80s movies and late-night HBO after his family fled Augusto Pinochet's dictatorship in Chile, seeking political asylum in Denmark before eventually ending up in the United States. Pascal always dreamed of being a performer, yes. And he spent years kicking around with small television roles and New York theater gigs before getting his eyes gouged out in *Game of Thrones*. But he never imagined becoming Hollywood's go-to reluctant father figure. You know, *famous*.

Maybe that's why Pascal now seems chiefly concerned with making those around him feel comfortable. When the shoot runs long, cutting into one-on-one time, he assures me he'll stick around to talk. And he does, for much longer than his schedule is supposed to allow. I get the feeling he's just excited to finally be sitting at the cool kids' table—Ethan Hawke! Nic freaking Cage!—and doesn't want to do anything to mess it up. Like most celebrities, there's a part of him that is a little insecure and hungry for validation; even an offhand compliment about one of his performances seems to set him at ease. He's most engaged when we talk about his family and politics. It comes through in his voice, his body language, a cleverly deployed arched eyebrow. He cares so much. He's also uncomfortable caring so much.

This is, I suspect, the source of his powers—that empathy at his core, visibly competing with the tough-guy exterior. Unlike most hero types these days, whose bodies glisten with smoothed-over perfection, Pascal has aged into his face. Whatever he lacks in shine, he makes up for in grit: His broad features and salt-and-pepper facial hair lend him a grizzled, protective air. In *The Last of Us*, he plays Joel Miller, a father in a postapocalyptic zombified wasteland dealing with loss both personal and global. The performance flicks between menace and heartbreak, infused with deep feeling—a natural ability to find the humanity at the heart of a conflicted hero. That's Pascal. *Our* conflicted hero. Empathy hugs and all.

WIRED: You seem to be picking parts—the Mandalorian, Joel in *The Last of Us*—that play very intentionally into a tough, conflicted outsider status. But maybe that's too neat and tidy?

PEDRO PASCAL: I find it funny when anyone applies choice to my experience. Of course you can say no to things, but you can't say no to Jon Favreau, Kathleen Kennedy, Dave Filoni, or HBO. It never felt like stopping and considering what the characters were. It was simply the circumstance of a door opening and stepping through it.

So there was nothing specifically tempting about *The Last of Us*?

To be totally honest, it was wanting to work with Craig Mazin, who did *Chernobyl*. Also, HBO is content that I literally grew up on. I experienced their original programming. Their original programming was very, very mature.

You mean, like, the after–11 pm original programming.

Absolutely. And I saw all of it, which is pretty nuts.

Your parents didn't care?

Obviously there's a variety of immigrant experiences in the US, but it tends to be really strict in one way and really open in another way. If my parents liked what they were watching, they rarely sent me out of the room. But I had to get good grades or I wasn't allowed to watch shit.

Same here—get good grades, do whatever you want.

They didn't take TV seriously as something that would influence our choices. But basically, I developed a real big dream about being a part of something that would be important to a network like HBO.

So how'd you prep for *The Last of Us*? Did you play the video game?

I hadn't heard of the game. Their instruction was: *Don't play the game*. I ignored them. I tried to play the game, and I was very, very bad at it. (But my nephew was fantastic.) It was important to me to play notes that were directly related to what was originally in the game—physically, visually, vocally.



STYLING BY FABIO IMMEDIATO. GROOMING BY MIRA CHAI HYDE / A. SPIEGELMAN MGMT USING OF SKUFF. TAILORING BY ABIGAIL LEWIS. STYLING ASSISTANCE BY ASMAE EL OUARIACH

PEDRO PASCAL DIDN'T MAKE IT BIG UNTIL HIS FORTIES. NOW HE WANTS TO TAKE CARE OF THE FRIENDS WHO SUPPORTED HIM THROUGH LEAN TIMES.

dously. Is it the fear of violence in general? Is it the fear of your own violence?

Or maybe the fear that you'll like it?
Totally. I love thrill-seeking stuff. But I don't make a practice of testing my limits. I'm actually a little bit opposed to it. I don't like pain.

Meaning physical pain?
Pain of every kind. I don't like psychological, emotional, or physical pain. Some people will be like, *Oh, I know that it's very likely I'll break something, I've got to try that.* Fuck. That. I don't think of myself as—I'm not a tough guy.

Really?
I don't live that way. I'm a lubricant. I want people to feel comfortable. I don't know how to function at the expense of anyone's comfort level. I'm a people pleaser.

I see some of that on social media, where you seem to do everything you can to make, say, the sci-fi fandom more welcoming and inclusive. You're very supportive of your sister, for example, who came out as trans in 2021. How are you navigating your role in political spaces?
Total improvisation and ultimately just erring on the side of, like … [*very long pause, two deep sighs*] My entire heart is set on, you know, the marginalized underdog. It's not a choice. Like, how dare anyone not support the people that are deserving of support, and are deserving of protection and need more of it than you do. Do you know what I mean?

Yeah, but some actors would say, *My star is rising, I don't want to get involved with this.* Maybe if you pause to think about it, it could keep you from doing the right thing. And this feels like the barest minimum. Like, the barest minimum.

You mean an Instagram post isn't enough?
No, it's not. My personal hope is to seize the opportunity to be of service in ways that are true. I'm keeping my eyes open. The truth is that I don't think I do nearly enough. I'm, like, a LIB-ER-AL, but there are contradictions there as well, because

Did you bring anything personal to the role?
That's the fun part—how much you get to externalize internal darkness in a safe way and bring in things that are from your nightmares.

Such as?
Joel's capacity for violence, and being good at it. I didn't get into any physical fights growing up, and definitely not as an adult. Violence scares me tremen-

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HEMAL JHAVERI *(@hemjhaveri) is* WIRED*'s managing editor.*

we live capitalistically. I guess we carry, you know, the weight of that shame?

The weight of capitalist shame? The fact that you make money is a bad thing?
Kind of?

You've had late-career success. You were consistently working—
I was consistently working, and it was a total struggle in such a typical way, but there was always somebody that would be able to bail me out—to help me pay my rent or help me get groceries.

But now you must be rolling around in all your money like Demi Moore.
[*Laughs*] Demi Moore in *Indecent Proposal*?

Yes.
I don't have the *bod* for that. She's basically the only one who could pull it off. Yeah, I get my cash. I spread it all over my bed and I roll around in it.

I knew it. But seriously, how do you think about your recent stardom?
I didn't get *Game of Thrones* till I was in my late thirties. And therefore, the amount of times I was helped, and the amount of people that I could rely on through some really tough times—I'm never going to let some of them ever buy dinner again. I want to take care of people as much as they took care of me.

Who helped you?
There's the family that my older sister sort of acquired. And then also by becoming part of a theater community that really looks after itself.

You have some famous friends too.
Does that mean we have to talk about Oscar [Isaac]?

The internet loves this friendship.
I met him through a play we did together in 2005. An off-Broadway show where we were getting $500 a week, before taxes.

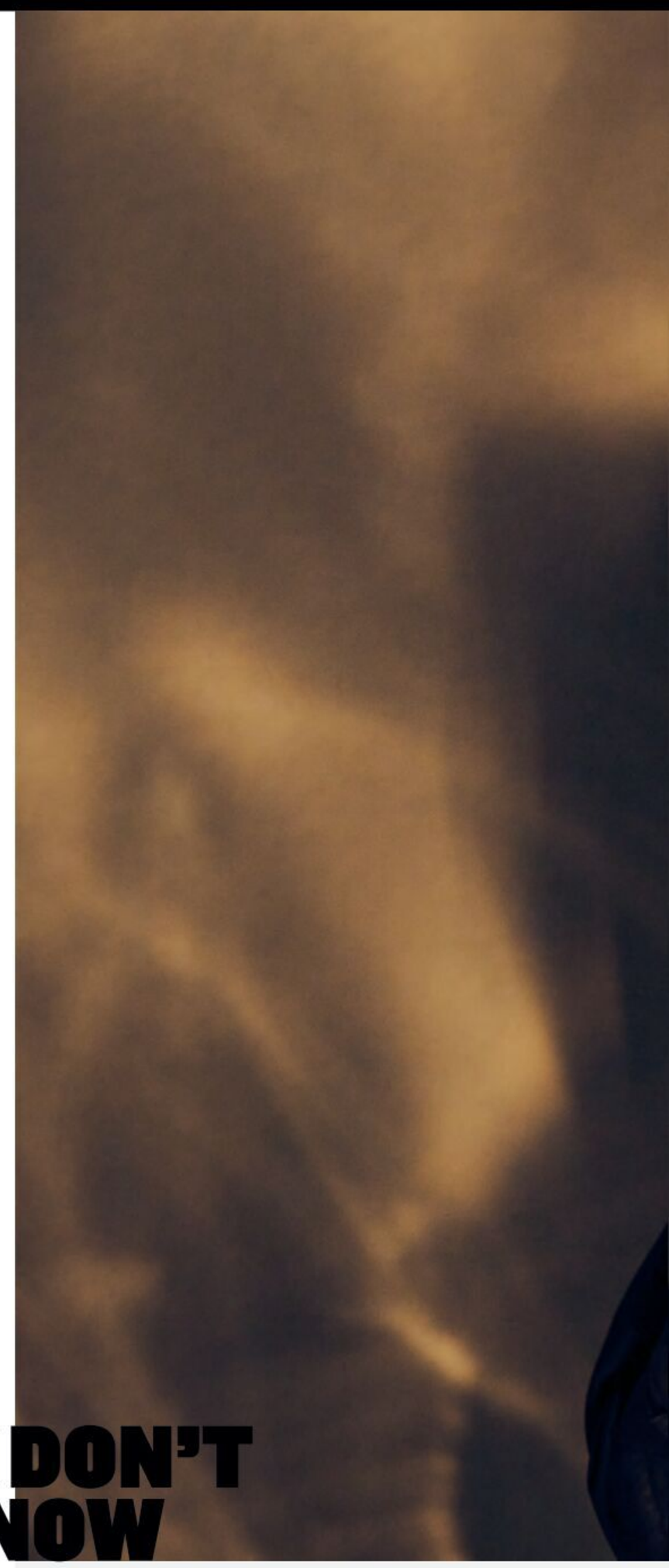
Do you have a favorite memory of the two of you?
There's so many. He's so naughty. His level of naughtiness onstage during that play, for example. He played a ghost, which meant that the living characters in the story could not see him. I had to do my scenes, and he would physically be there, but because my character couldn't see him, he could fuck with me, all in front of live audiences, as much as he wanted, trying to get me to crack up or forget my lines. The memory is simultaneously dark and wonderful.

Would you say you tend to be a hopeful, forward-looking guy?
We have to hope. But I'm too privileged. You know what I mean? Like, I'm too lucky. It's an interesting thing. The reason my older sister and I grew up in the States is because my parents fled a military dictatorship. So, you know, only 10 years after my parents were in hiding, I was crying because *The Breakfast Club* was checked out at the video store.

But I'm guessing there were also challenges?
Looking back, so much of it only seems to present itself as an opportunity. When my parents ended up on a list of pardoned exiles and were able to go back to Chile, it came with enormous families on both sides, which was missing from the experience of growing up in the States. I guess it's only in middle age where it feels like it can be emotionally challenging to accept that there isn't anywhere to plant my flag as an individual. Everywhere is home and nowhere is home. But that also still feels like a good thing to me. It's often framed as a disadvantage in our culture, but it's an advantage in character, and in perspective, and in outlook.

Do you think that if you had popped into national consciousness when you were younger, you would not have wanted, say, a traditional Marvel role—the cape and the CGI and all that?
But I do want that. I want to be in movies.

But the world's in a fairly tense political moment right now. Does that change what it means to be a hero?
There's so many ways to misunderstand people and to forget that, at the end of the day, your neighbor is very likely to give you the shirt off their own back. The interchanges that you have with strang-



"I DON'T KNOW HOW TO FUNCTION AT THE EXPENSE OF ANYONE'S COMFORT LEVEL. I'M A PEOPLE PLEASER."

—PEDRO PASCAL



ers are, more often than not, human. But then you can go and look shit up and be terrified by how divided we all apparently are. To comfort myself, I just remember that everybody I come in contact with is sort of, in their own way, heroically kind.

In some ways, you're the face of that new kind of hero.
Oh my gosh. It's funny when the phrasing "the face of" comes up, because Mando is faceless. I haven't thought about it in that way. I'm always struggling to imagine myself as being a part of something that I have been witness to growing up and watching. There's a disconnect for me—I don't know how to place myself in that world. Like, I just go a little blank.

Then talk about your character in *The Last of Us*. Joel can be a little scary.
I think what's scary about Joel is that none of us really know what we'd be capable of if faced with the idea of losing love. Whether it's conscious or unconscious, being alive or even being a human being is directly connected to the love you feel. Existing is connected to the love you feel toward a particular relationship—your child, your partner—and to lose that? Some people are not capable of applying rational thought to that kind of loss, or the threat of that loss, or the threat of that loss again, right?

That's what makes you human.
That's what makes you human *and inhuman*. It's such a beautiful question that the video game poses. I avoid all of it by not having kids. And staying out of relationships.

Do you want kids?
I don't know.

You're close with your nephews.
Well, yes. Only because they were so good at playing *The Last of Us*. No, I'm just kidding.

It's funny then, or at least a bit ironic, that you keep getting cast as these reluctant father figures.
I love being … I like being able to imagine it.

THE LAST OF US IS AVAILABLE MONDAYS ON SKY ATLANTIC AND THE NOW STREAMING SERVICE

JUMPSUIT: HERMES (FIRST AND THIRD PORTRAITS); SHIRT AND TROUSERS (SECOND PORTRAIT): BRIONI; BOOTS: GIANVITO ROSSI



illustration by

OFF-SITE RESEARCH FACILITY

Generative AI can now make
better art than most humans.

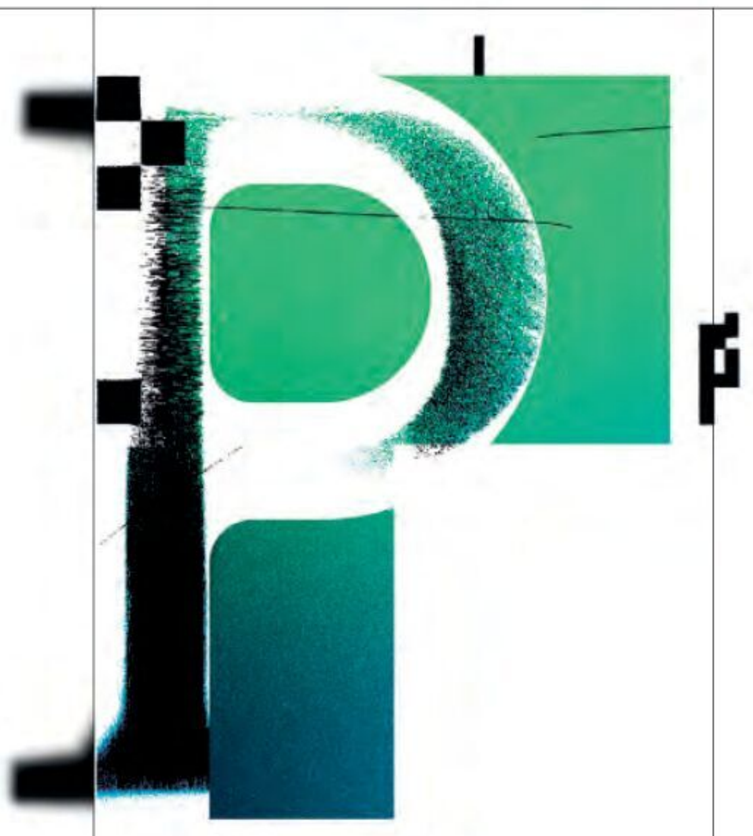


ENGINES OF WOW

Soon it will transform how we
design just about everything.

by KEVIN KELLY





PICTURE LEE UNKRICH, ONE OF PIXAR'S MOST distinguished animators, as a seventh grader. He's staring at an image of a train locomotive on the screen of his school's first computer. *Wow,* he thinks. Some of the magic wears off, however, when Lee learns that the image had not appeared simply by asking for "a picture of a train." Instead, it had to be painstakingly coded and rendered—by hard-working humans.

Now picture Lee 43 years later, stumbling onto DALL-E, an artificial intelligence that generates original works of art based on human-supplied prompts that can literally be as simple as "a picture of a train." As he types in words to create image after image, the *wow* is back. Only this time, it doesn't go away. "It feels like a miracle," he says. "When the results appeared, my breath was taken away and tears welled in my eyes. It's that magical."

Our machines have crossed a threshold. All our lives, we have been reassured that computers were incapable of being truly creative. Yet, suddenly, millions of people are now using a new breed of AIs to generate stunning, never-before-seen pictures. Unlike Lee Unkrich, most of these users are not professional artists, and that's the point: They do not have to be. Not everyone can write, direct, and edit an Oscar winner like *Toy Story 3* or *Coco,* but everyone *can* launch an AI image generator and type in an idea. What appears on the screen is astounding in its realism and depth of detail. Thus the universal response: *Wow*. On four services alone—Midjourney, Stable Diffusion, Artbreeder, and DALL-E—humans working with AIs now cocreate more than 20 million images every day. With a paintbrush in hand, artificial intelligence has become an engine of wow.

Because these surprise-generating AIs have learned their art from billions of pictures made by humans, their output hovers around what we expect pictures to look like. But because they are an alien AI, fundamentally mysterious even to their creators, they restructure the new pictures in a way no human

KEVIN KELLY
(@kevin2kelly) is the founding executive editor of WIRED.

A MESSAGE FROM THE WIRED ART DEPARTMENT: Though it was only a matter of time before automation came for creativity, the advent of AI art generators has been divisive in the creative community. Some artists have embraced the new tech; others believe it's #notreal. We at WIRED have spent a lot of time sorting out our own reactions. Undeniably, the technology comes with issues—economic, ethical, legal. At the same time, it expands opportunities for art and artistry. WIRED will always come down on the side of the future. That means encouraging the use of new tools, while refusing to allow those tools to replace human creators.

is likely to think of, filling in details most of us wouldn't have the artistry to imagine, let alone the skills to execute. They can also be instructed to generate more variations of something we like, in whatever style we want—in seconds. This, ultimately, is their most powerful advantage: They can make new things that are relatable and comprehensible but, at the same time, completely unexpected.

So unexpected are these new AI-generated images, in fact, that—in the silent awe immediately following the *wow*—another thought occurs to just about everyone who has encountered them: Human-made art must now be over. Who can compete with the speed, cheapness, scale, and, yes, wild creativity of these machines? Is art yet another human pursuit we must yield to robots? And the next obvious question: If computers can be creative, what else can they do that we were told they could not?

I have spent the past six months using AIs to create thousands of striking images, often losing a night's sleep in the unending quest to find *just one more* beauty hidden in the code. And after interviewing the creators, power users, and other early adopters of these generators, I can make a very clear prediction: Generative AI will alter how we design just about everything. Oh, and not a single human artist will lose their job because of this new technology.



IT IS NO EXAGGERATION TO CALL images generated with AI *cocreations*. The sobering secret of this new power is that the best applications of it are the result not of typing in a single prompt but of very long conversations between humans and machines. Progress for each image comes from many, many iterations, back-and-forths, detours, and hours, sometimes days, of teamwork—all on the back of years of advancements in machine learning.

AI image generators were born from the marriage of two separate technologies. One was a historical line of deep-learning neural nets that could generate coherent realistic images, and the other was a natural language model that could serve as an interface to the image engine. The two were combined into a language-driven image generator. Researchers scraped the internet for all images that had adjacent text, such as captions, and used billions of these examples to connect visual forms to words, and words to forms. With this new combination, human users could enter a string of words—the prompt—that described the image they sought, and the prompt would generate an image based on those words.

Scientists now at Google invented the diffusion computational models that are at the core of image generators today, but the company has been so concerned about what people might do with them that it still has not opened its own experimental generators, Imagen and Parti, to the public. (Only employees can try them, and with tight guidelines on what can be requested.) It is no coincidence, then, that the three most popular platforms for image generators right now are three startups with no legacy to protect. Midjourney is a bootstrapping startup launched by David Holz, who based the generator in an emerging community of artists. The interface to the AI is a noisy Discord server; all the work and prompts were made public from the start. DALL-E is a second-gen product of the nonprofit OpenAI, funded by Elon Musk and others. Stable Diffusion appeared on the scene in August 2022, created by Emad Mostaque, a European entrepreneur. It's an open source project, with the added benefit that anyone can download its software and run it locally on their own desktop. More than the others, Stable Diffusion has unleashed AI image generators into the wild.

Why are so many people so excited to play with these AIs? Many images are being created for the same reason that humans have always made most art: because the images are pretty and we want to look at them. Like flames in a campfire, the light patterns are mesmerizing. They never repeat themselves; they surprise, again and again. They depict scenes no one has witnessed before or can even imagine, and they are expertly composed. It's a pleasure similar to exploring a video game world, or paging through an art book. There is a real beauty to their creativity, and we stare much in the way we might appreciate a great art show at a museum. In fact, viewing a parade of generated images is very much like visiting a personal museum—but in this case, the walls are full of art we ask for. And the perpetual novelty and surprise of the next image hardly wanes. Users may share the gems they discover, but my guess is that 99 percent of the 20 million images currently generated each day will only ever be viewed by a single human—their cocreator.

Like any art, the images can also be healing. People spend time making strange AI pictures for the same reason they might paint on Sundays, or scribble in a journal, or shoot a video. They use the media to work out something in their own lives, something that can't be said otherwise. I've seen images depicting what animal heaven might look like, created in response to the death of a beloved dog. Many images explore the representation of intangible, spiritual realms, presumably as a way to think about them. "A huge portion of the entire usage is basically art therapy," Holz, the Midjourney creator, tells me. "The images are not really aesthetically appealing in a universal sense but are appealing, in a very deep way, within the context of what's going on in people's lives." The machines can be used to generate fantasies of all types. While the hosted services prohibit porn and gore, anything goes on the desktop versions, as it might in Photoshop.

AI-generated pictures can be utilitarian too. Say you are presenting a report on the possibility of recycling hospital plastic waste into construction materials and you want an image of a house made out of test tubes. You could search stock photo markets for a usable image made by a human artist. But a unique assignment like this rarely yields a preexisting picture, and even if found, its copyright status could be dubious or expensive. It is cheaper, faster, and probably far more appropriate to generate a unique, personalized image for your report in a few minutes that you can then insert into your slides, newsletter, or blog—and the copyright ownership is yours (for now). I have been using these generators myself to cocreate images for my own slide presentations.

In an informal poll of power users, I found that only about 40 percent of their time is spent seeking utilitarian images. Most AI images are used in places where there were no images previously. They usually do not replace an image created by a human artist. They may be created, for example, to illustrate a

JAMES MARSHALL

text-only newsletter by someone without artistic talent themselves, or the time and budget to hire someone. Just as mechanical photography did not kill human illustrations a century ago, but rather significantly expanded the places in which images appeared, so too do AI image generators open up possibilities for more art, not less. We'll begin to see contextually generated images predominately in spaces that are currently blank, like emails, text messages, blogs, books, and social media.

This new art resides somewhere between painting and photography. It lives in a possibility space as large as painting and drawing—as huge as human imagination. But you move through the space like a photographer, hunting for discoveries. Tweaking your prompts, you may arrive at a spot no one has visited before, so you explore this area slowly, taking snapshots as you step through. The territory might be a subject, a mood, or a style, and it might be worth returning to. The art is in the craft of finding a new area and setting yourself up there, exercising good taste and the keen eye of curation in what you capture. When photography first appeared, it seemed as if all the photographer had to do was push the button. Likewise, it seems that all a person has to do for a glorious AI image is push the button. In both cases, you get an image. But to get a great one—a truly artistic one—well, that's another matter.

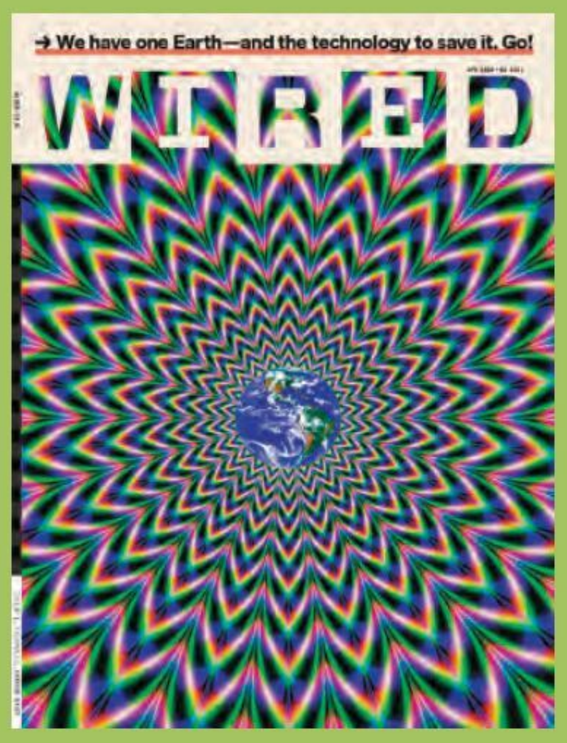


ACCESSIBLE AI IMAGE GENERATORS are not even a year old, but already it is evident that some people are much better at creating AI images than others. Although they're using the same programs, those who have accumulated thousands of hours with the algorithms can magically produce images that are many times better than the average person's. The images by these masters have a striking coherence and visual boldness that is normally overwhelmed by the flood of details the AIs tend to produce. That is because this is a team sport: The human artist and the machine artist are a duet. And it requires not just experience but also lots of hours and work to produce something useful. It is as if there is a slider bar on the AI: At one end is Maximum Surprise, and at the other end Maximum Obedience. It is very easy to get the AI to surprise you. (And that is often all we ask of it.) But it is very difficult to get the AI to obey you. As Mario Klingemann, who makes his living selling NFTs of his AI-generated artwork, says, "If you have a very specific image in mind, it always feels like you are up against a force field." Commands like "shade this area," "enhance this part," and "tone it down" are obeyed reluctantly. The AIs have to be persuaded.

Current versions of DALL-E, Stable Diffusion, and Midjourney limit prompts to about the length of a long tweet. Any longer and the words muddle together; the image turns to mush. That means that behind every fabulous image lies a short magic spell that summons it. It begins with the first incantation. How you say it matters. Your immediate results materialize in a grid of four to nine images. From that batch of pictures, you variate and mutate offspring images. Now you have a brood. If they look promising, begin to tweak the spell to nudge it in new directions as it births more generations of

TAKE TWO

AI image generators don't just spit out random acts of art. They must be "prompted"—carefully guided by their human users. So we asked eight of our favorite artists to re-create their original WIRED covers using these new tools. "For the prompts, I started by mixing nonsense words and techniques," says Alvaro Dominguez, who designed our 2020 Climate Issue cover (below). "For example: 'a 3D render of an oil painting.' What is that? I don't know. But I'm trying to bring life to something generated by a machine." Judge the results for yourself—here and on the following pages.



Alvaro Dominguez, ILLUSTRATOR

28.04: We have one Earth...



← “A 3D render of a robotic metallic earth with wires in synthwave style.”



← “A 3D render of earth as a machine with a control panel and many buttons, rainbows, technology, sparkles and flowers”

→ “An oil painting of pixelated planet Earth and robots flying around with a lot of rainbows in Jonas Wood style”







→ “A 3D render of planet Earth with the face of a smiley robot inside being part of mother board with monster truck wheels in the style of Jonas Wood”













← “A 3D render of the planet Earth dancing in a robot party, in the style of Jonas Wood, digital art”

→ “An oil painting of pixelated planet Earth and robots flying around with a lot of rainbows in Jonas Wood style”













← “A 3D render of an oil painting of Earth in space surrounded by flowers and technology computer motherboard in Robert Irwin style”

images. Multiply the group again and again as you search for the most compelling composition. Do not despair if it takes dozens of generations. Think like the AI; what does it like to hear? Whisper instructions that have worked in the past, and add them to the prompt. Repeat. Change the word order to see whether it likes that. Remember to be specific. Replicate until you have amassed a whole tribe of images that seem to have good bones and potential. Now cull out all but a select few. Be merciless. Begin outpainting the most promising images. That means asking the AI to extend the image out in certain directions beyond the current borders. Erase those portions that are not working. Suggest replacements to be done by the AI with more incantations (called inpainting). If the AI is not comprehending your hints, try spells used by others. When the AI has gone as far as it can, migrate the image to Photoshop for final tailoring. Present it as if you have done nothing, even though it is not uncommon for a distinctive image to require 50 steps.

Behind this new magecraft is the art of prompting. Each artist or designer develops a way of persuading an AI to yield its best by evolving their prompts. Let's call these new artists AI whisperers, or prompt artists, or promptors. The promptors work almost as directors, guiding the work of their alien collaborators toward a unified vision. The convoluted process required to tease a first-rate picture out of an AI is quickly emerging as a fine-art skill. Almost daily, new tools arrive to make prompting easier, better. PromptBase is a market for promptors to sell prompts that create simple images such as emoticons, logos, icons, avatars, and game weapons. It's like clip art, but instead of selling the art, they sell the prompt that generates the art. And unlike fixed clip art, it is easy to alter and tweak the art to fit your needs, and you can extract multiple versions again and again. Most of these prompts sell for a couple bucks, which is a fair price, given how much trouble it is to hone a prompt on your own.

Above-average prompts not only include the subject but also describe the lighting, the point of view, the emotion evoked, the color palette, the degree of abstraction, and perhaps a reference picture to imitate. As with other artistic skills, there are now courses and guidebooks to train the budding promptor in the finer points of prompting. One fan of DALL-E 2, Guy Parsons, put together a free Prompt Book, jammed with tips on how to go beyond the wow and get images you can actually use. One example: If your prompt includes specific terms such as "Sigma 75 mm camera lens," Parson says, then the AI doesn't just create that specific look made by the lens; "it more broadly alludes to 'the kind of photo where the lens appears in the description,'" which tends to be more professional and therefore yields higher-quality images. It's this kind of multilevel mastery that produces spectacular results.

For technical reasons, even if you repeat the exact same prompt, you are unlikely to get the same image. There is a randomly generated seed for each image, without which it is statistically impossible to replicate. Additionally, the same prompt given to different AI engines produces different images—Midjourney's are more painterly, while DALL-E is optimized for photographic realism. Still, not every promptor wishes to share their secrets. The natural reaction upon seeing a particularly brilliant image is to ask, "What spell did you use?" What was the prompt? Robyn Miller, cocreator of the legendary game *Myst* and a pioneering digital artist, has been posting an AI-generated image every day. "When people ask me what prompt I used," he says, "I have been surprised that I don't want to tell them. There is an art to this, and that has also surprised me." Klingemann is famous for not sharing his prompts. "I believe all images already exist," he says. "You don't make them, you find them. If you get somewhere by clever prompting, I do not see why I want to invite everybody else there."

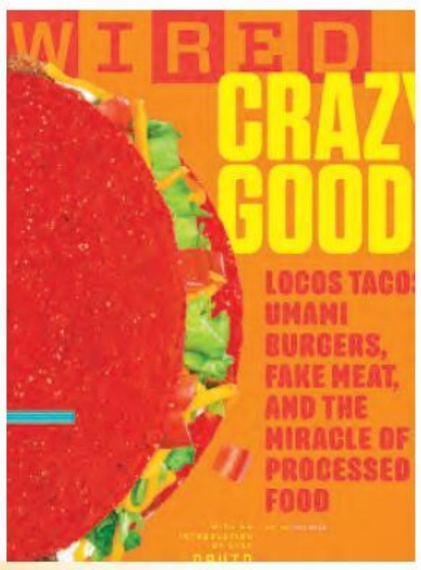
It seems obvious to me that promptors are making true art. What is a consummate movie director—like Hitchcock, like Kurosawa—but a promptor of actors, actions, scenes, ideas? Good image-generator promptors are engaged in a similar craft, and it is no stretch for them to try and sell their creations in art galleries or enter them into art contests. This summer, Jason Allen won first place in the digital art category at the Colorado State Fair Fine Art competition for a large, space-opera-themed canvas that was signed "Jason Allen via Midjourney." It's a pretty cool picture that would've taken some effort to make no matter what tools were used. Usually images in the digital art category are created using Photoshop and Blender-type tools that enable the artist to dip into libraries of digitized

Dan Winters, PHOTOGRAPHER

21.10: Crazy Good!

"Using AI was entertaining and somewhat inspirational. It's funny—this is actually a better cover than the one that ran."

PROMPT: "Pixelated taco centered on robins egg blue solid color"





Ian Allen, PHOTOGRAPHER

22.01: Heads Up

"It's currently not amazing. But it's also not terrible."

PROMPT: "A graphic close photographic portrait of a man wearing google glasses and various HUDs"





objects, textures, and parts, which are then collaged together to form the scene. They are not drawn; these digital images are unapologetically technological assemblages. Collages are a venerable art form, and using AI to breed a collage is a natural evolution. If a 3D-rendered collage is art, then a Midjourney picture is art. As Allen told Vice, "I have been exploring a special prompt. I have created hundreds of images using it, and after many weeks of fine-tuning and curating my gens, I chose my top three and had them printed on canvas."

Of course, Allen's blue ribbon set off alarm bells. To some critics, this was a sign of the end times, the end of art, the end of human artists. Predictable lamentations ensued, with many pointing out how unfair it felt for struggling artists. The AIs are not only going to take over and kill us all—they are, apparently, going to make the world's best art while doing so.



AT ITS BIRTH, EVERY NEW TECHnology ignites a Tech Panic Cycle. There are seven phases:

1. Don't bother me with this nonsense. It will never work.
2. OK, it is happening, but it's dangerous, 'cause it doesn't work well.
3. Wait, it works too well. We need to hobble it. Do something!
4. This stuff is so powerful that it's not fair to those without access to it.
5. Now it's everywhere, and there is no way to escape it. Not fair.
6. I am going to give it up. For a month.
7. Let's focus on the real problem—which is the next current thing.

Today, in the case of AI image generators, an emerging band of very tech-savvy artists and photographers are working out of a Level 3 panic. In a reactive, third-person, hypothetical way, they fear other people (but never themselves) might lose their jobs. Getty Images, the premier agency selling stock photos and illustrations for design and editorial use, has already banned AI-generated images; certain artists who post their work on DeviantArt have demanded a similar ban. There are well-intentioned demands to identify AI art with a label and to segregate it from "real" art.

Beyond that, some artists want assurances that their own work not be used to train the AIs. But this is typical of Level 3 panic—in that it is, at best, misguided. The algorithms are exposed to 6 billion images with attendant text. If you are not an influential artist, removing your work makes zero difference. A generated picture will look exactly the same with or without your work in the training set. But even if you are an influential artist, removing your images still won't matter. Because your style has affected the work of others—the definition of influence—your influence will remain even if your images are removed. Imagine if we removed all of Van Gogh's pictures from the training set. The style of Van Gogh would still be embedded in the vast ocean of images created by those who have imitated or been influenced by him.

Styles are summoned via prompts, as in: "in the style of Van Gogh." Some unhappy artists would rather their names not be permitted as prompts. So even if their influence can't be removed, you can't reach it because their name is off-limits. As we know from all previous attempts at censoring, these kinds of speech bans are easy to work around; you can misspell a name, or simply describe the style in words. I found, for example, that I could generate detailed black-and-white natural landscape photographs with majestic lighting and prominent foregrounds—without ever using Ansel Adams' name.

There is another motivation for an artist to remove themselves. They might fear that a big corporation will make money off their work, and their contribution won't be compensated. But we don't compensate human artists for their influence on other human artists. Take David Hockney, one of the highest-paid living artists. Hockney often acknowledges the great influence other living artists have on his work. As a society, we don't expect him (or others) to write checks to his influences, even though he could. It's a stretch to think AIs should pay their influencers. The "tax" that successful artists pay for their success is their unpaid influence on the success of others.

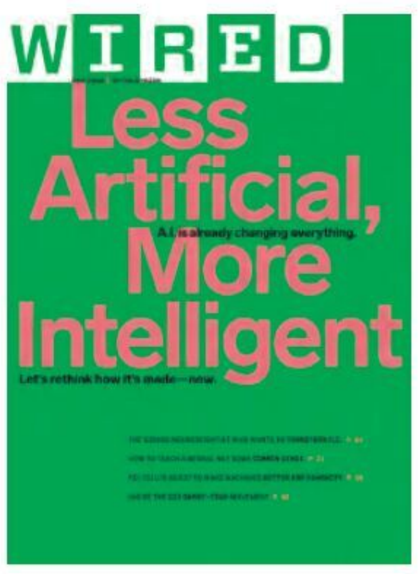
What's more, lines of influence are famously blurred, ephemeral, and imprecise. We are all influenced by every-

Margaret Swart, DESIGNER & FORMER WIRED ART DIRECTOR

26.12: Less Artificial, More Intelligent

"I tried illustrations because I thought I might get something interesting. No such luck."

PROMPT: "Type illustrations 'Less' 'Artificial' 'More' 'Intelligent'"



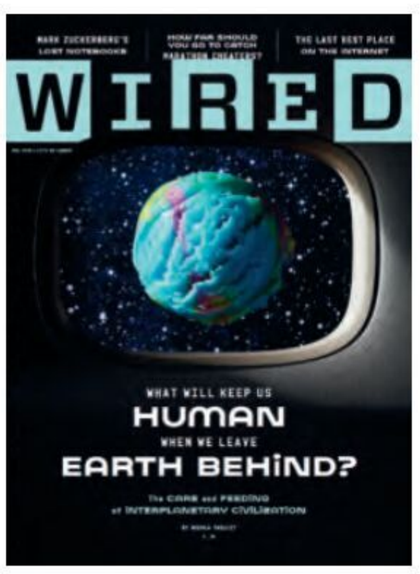


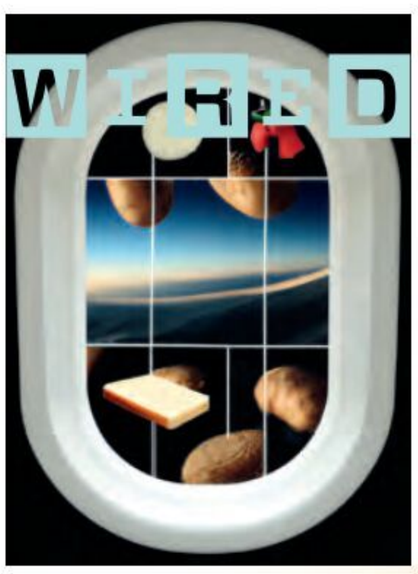
Stephanie Gonot, PHOTOGRAPHER

28.02: What Will Keep Us Human ... ?

"I'm hooked!"

PROMPT: "Mysterious photo of food floating in outerspace through a spaceship window"





OPEN AI/DALL-E2

Art Is Human

by ADAM GARCIA



Art Is Hybrid

by AURANOVA AI + MIDJOURNEY



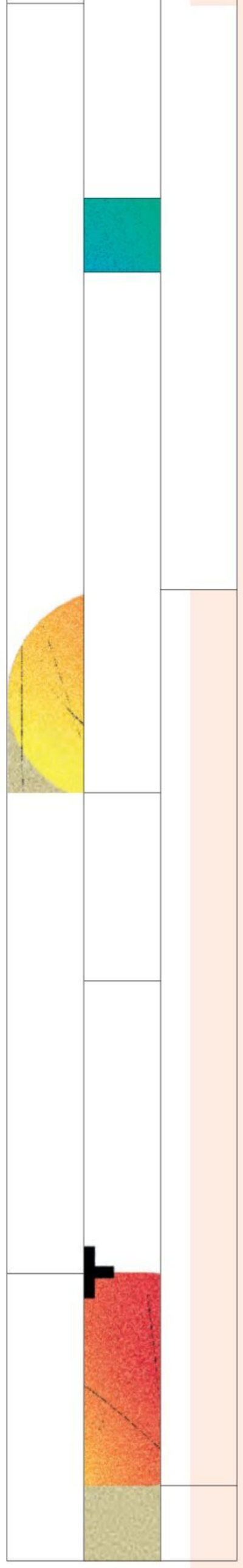
thing around us, to degrees we are not aware of and certainly can't quantify. When we write a memo or snap a picture with our phone, to what extent have we been influenced—directly or indirectly—by Ernest Hemingway or Dorothea Lange? It's impossible to unravel our influences when we create something. It is likewise impossible to unravel the strands of influence in the AI image universe. We could theoretically construct a system to pay money earned by the AI to artists in the training set, but we'd have to recognize that this credit would be made arbitrarily (unfairly) and that the actual compensatory amounts per artist in a pool of 6 billion shares would be so trivial as to be nonsensical.

In the coming years, the computational engine inside an AI image generator will continue to expand and improve until it becomes a central node in whatever we do visually. It will have literally seen everything and know all styles, and it will paint, imagine, and generate just about anything we need. It will become a visual search engine and a visual encyclopedia with which to understand images, and the primary tool we use with our most important sense, our sight. Right now, every neural net algorithm running deep in the AIs relies on massive amounts of data—thus the billions of images needed to train it. But in the next decade, we'll have operational AI that relies on far fewer examples to learn, perhaps as few as 10,000. We'll teach even more powerful AI image generators how to paint by showing them thousands of carefully curated, highly selected images of existing art, and when this point comes, artists of all backgrounds will be fighting one another to be included in the training set. If an artist is in the main pool, their influence will be shared and felt by all, while those not included must overcome the primary obstacle for any artist: not piracy, but obscurity.



AS SOON AS 2D GENERATIVE ALGORITHMS were born, experimenters rushed to figure out what was next. Jensen Huang, the ambitious cofounder of Nvidia, believes the next generation of chips will generate 3D worlds for the metaverse—"the next computing platform," as he calls it. In a single week this past September, three novel text-to-3D/video image generators were announced: GET3D (Nvidia), Make-a-Video (Meta), and DreamFusion (Google). The expansion is happening faster than I can write. Amazing as frameable 2D pictures produced by AI are, outsourcing their creation is not going to radically change the world. We are already at peak 2D. The genuine superpower being released by AI image generators will be in producing 3D images and video.

A future prompt for a 3D engine might look something like this: "Create the messy bedroom of a teenager, with posters on the wall, an unmade bed, and afternoon sunlight streaming through closed blinds." And in seconds, a fully realized room is born, the closet door open and all the dirty clothes on the floor—in full 3D. Then, tell the AI: "Make a 1970s kitchen with refrigerator magnets and all the cereal boxes in the pantry. In full volumetric detail. One that you could walk through. Or that could be photographed in a video." Games crammed with alternatively rendered worlds and full-length movies decked out with costumes and sets have eternally been out



THERE'S A HILARIOUS illustration from Paris in late 1839, mere months after an early type of photograph called a daguerreotype was announced to the world, that warned what this innovation portended. In Théodore Maurisset's imagination, the daguerreotype would bring about a collective hysteria, in which crazed masses arrive from the ends of the earth and overrun a small photo studio. The clamor is so feverish it brings about a mass hallucination, in which nearly everything else in the landscape, including railroad cars, a clock tower, a basket for a hot-air balloon—anything remotely boxy in shape—morphs into cameras. As they march to the studio, the crowds pass by half a dozen gallows where, in response to the daguerreotype's appearance, artists have hung themselves. The people hardly notice.

What a ruckus! What panic! And why not? Until the appearance of photography, painters had nearly a monopoly on artistic representation. But now those silly photographers, most of whom were rank amateurs or, worse, disloyal or failed artists, would get the job. Upon seeing a daguerreotype for the first time around 1840, the French painter Paul Delaroche, whose own students would soon defect to photography, was said to have cried out, "From today, painting is dead!"

The history of painting's early relationship with photography is not perfectly analogous to the conundrum caused by today's AI art, made by image generators like DALL-E 2, Midjourney, and Stable Diffusion. But compare Delaroche's exclamation to the crowing of Jason Allen of Pueblo West, Colorado, who took home first prize for his AI-generated entry in an art competition at the state fair last September. The $300 prize was modest, but that didn't stop Allen from gloating. "Art is dead, dude," he said afterward. "It's over. AI won. Humans lost."

In the 19th century, painting, at least, did not die. Or even suffer a mild cold. Painters did not lose jobs, and Delaroche himself went on to paint some of his most monumental and ambitious work.

Still, Maurisset's vision of the masses rampaging the landscape was not totally wrong. The people who wanted to sit before the camera or sought cameras for themselves were not only countless but diverse. They were a different group of patrons than those supporting painters, tending to be from the middle and working classes, whose previous ability to buy or make images was almost nil. During an age that included reforms to expand the vote, early activism for women's rights, and the abolition of slavery, the camera acquired a democratic air. Frederick Douglass, the abolitionist and former slave, had over 160 portraits taken—more than any other American in the 19th century—in the belief that through them he could insist on his self-worth and dignity. The camera was potentially everybody's tool (it wasn't exactly, but that was the promise), and such a thing had rarely been said about painting.

In those early days, the two media tended to have different markets. Even the most skilled and art-minded photographers were always fighting the lowly status accorded their craft by the art establishment. Whereas painting as a studio practice became a standard college offering as early as the 1860s (at least in New England), it took photography another 75 years to find a tenuous footing in higher education.

The earliest cameras tended to be large contraptions, requiring a sturdy tripod and finagling with chemicals. They had very slow shutters and needed lots of light, and a darkroom within shouting distance. They therefore tended to be best suited for subjects that were rooted in place: trinkets and knickknacks around the house, buildings, still lifes, landscapes—anything that didn't disturb focus or exposure. It was perhaps predictable, if gruesome, that when early photographers went to the war front, they sought not the action of battle but the corpses that remained afterward. The pictures that resulted, ironically, promoted even more those stilled or frozen subjects among painters, and they eventually helped reverse the hierarchy of painterly ambition, from the pursuit of complicated narrative paintings to scenes and objects of everyday life.

Cameras also brought a new awareness to *how* we see. Especially after manufacturers introduced the humble handheld camera, painters discovered modes of looking previously considered unworthy of the canvas: the casual glance, the momentary glimpse, the uncomfortable stare; or, in a bawdier vein, the paparazzi glare, the voyeuristic peek, the secret spying. With cameras there is always the risk of the blur, the out-of-focus, the unintended, and the serendipitous; and it is one of the orthodoxies in the history of art that modernist modes of expression explored all of them. Indeed, it's hard to look at some masterpieces from the late 19th century—say, all those sun-drenched, blurry haystacks by Monet, or the leafy, happy café scenes of Renoir, or those weirdly placed, yawning, stretching, off-kilter ballerinas by Degas—and not recognize the impact of photographs.

The influence went the other way too. To photographers who fancied themselves artists (not "operators," as they called those whom they viewed as commercial hacks), the darkroom was like a painter's studio, the touching and retouching of the negative like a studio practice. Julia Margaret Cameron, the Victorian photographer who re-created scenes from English literature, frequently made a mess of the large glass plate negatives. She got her fingerprints all over the emulsion, smudged the surface, over- and underexposed the print, and awkwardly highlighted the out-of-focus and accidental portions of the image. To a commercial photographer, those blips and blobs were imperfections to avoid. To Cameron, they were aspects to cultivate because they resembled the idiosyncratic choices and handcrafted manipulations of the genius-painter.

Those photographers who actually cared about opinion and profit, too, regularly refined their work to concoct acceptable prints for their patrons. In all of these manipulations, they relied on an aesthetic sensibility cultivated by painters. A portrait or a landscape looked right when it looked like a painter's version. The very first photographic team in Scotland incorporated this understanding into their process: Robert Adamson, an engineer and millwright by training, took the photographs and handed

THE PAST IS PHOTOG

WHEN THE CAMERA ARRIVED ON THE SCENE, PAINTERS DECLARED ART DEAD. SOUND FAMILIAR?

by ANTHONY W. LEE



GETTY IMAGES

the negatives over to his partner, David Octavius Hill, a painter by profession, to gussy them up. For portraiture, the trade journals referred to "the Rembrandt style," to signal the example the photographer ought to follow. And in a phrase that revealed the associations some photographers wanted to cultivate, the journals regularly referred to them as "sun painters."

For all that, photography was still regarded by most contemporaries as a technology that bypassed human touch. The sun, camera, lens, shutter, and silvered surface seemed to do all the work; the operator appeared merely to get the process going. Sure, it required knowledge of chemicals, glass, and optics (and a tolerance for noxious fumes), but those were thought peripheral to artistry—peripheral to the painter's concerns with oils and brushes and the translation of feeling and thought into painted surfaces. It's not identical to accusations of lack of imagination that some artists make of AI-generated pictures today. But the point is taken: The new tool is ersatz.

From the perspective of 1839, perhaps the most unlikely development in the fine-art scene was the opportunity for collaboration. To early observers, the camera's black-and-white image was a sign of its novelty, but the craze was quickly augmented by the demand for color. Photographers started hiring painters, who added all sorts of details to photographs, frequently with oil paint but also with watercolors, crayons, and chalk. The practice, begun in Europe and later especially popular and refined in Japan, took on a more flamboyant quality in the US. A sitter wanted rosier cheeks? You got it! Maybe some blue eyes? Let's try different shades! Or how about a sitter who wanted something she couldn't bring to the studio (or couldn't afford), like a diamond ring? Look how big we can make it! The additions could be piecemeal—a bit of rouge here, a dab of gold there—or more sweeping, with the brushwork covering most of the image and producing a weird hybrid picture. Over time, the collaborations could become more structured. In the treaty ports of China, for example, some entrepreneurs set up businesses with separate photography and painting departments and offered both media to clients.

Pace the pronouncements of Delaroche and Mauris-set—and, in our time, Jason Allen—it's always too soon to sound the death knell of painting or painters. Painting as a fine art will persist; much of the high-end gallery scene promotes and relies on it. And for many, the tactility of putting brush on canvas is an intimate and joyous form of expression that simply cannot be replaced. But if painting's dance with photography in the 19th century is any indication, there may well be a period of mutual influence, give and take, and perhaps collaboration between some artists and the machine. As Degas once told a painter friend who wanted nothing to do with newfangled amusements, "You need the natural life. I, the artificial."

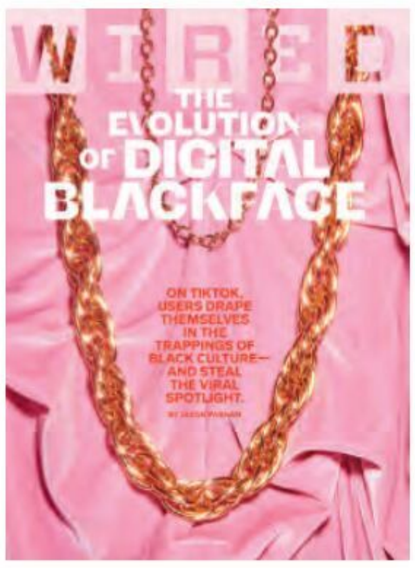
ANTHONY W. LEE is a professor of art history at Mount Holyoke College in Massachusetts.

Jessica Pettway, PHOTOGRAPHER

28.09: The Evolution of Digital Blackface

"It wasn't necessary to add 'white' to phrases. That was assumed."

PROMPTS: built with words like "hoop earring," "mouth smiling wearing grills," "white hand with super long nails pointing"





of reach for individual artists, who remain under the power of large dollars. AI could make games, metaverses, and movies as quick to produce as novels, paintings, and songs. Pixar films in an instant! Once millions of amateurs are churning out billions of movies and endless metaverses at home, they will hatch entirely new media genres—virtual tourism, spatial memes—with their own native geniuses. And when big dollars and professionals are equipped with these new tools, we'll see masterpieces at a level of complexity never seen before.

But even the vast universes of 3D worlds and video are not vast enough to contain the disruption that AI image generators have initiated. DALL-E, Midjourney, and Stable Diffusion are just the first versions of generative machines of all types. Their prime function, pattern recognition, is almost a reflex for human brains, something we accomplish without conscious thinking. It is at the core of almost everything we do. Our thinking is more complex than just pattern recognition, of course; dozens of cognitive functions animate our brain. But this single type of cognition, synthesized in machines (and the only cognition we have synthesized so far), has taken us further than we first thought—and will probably continue to advance further than we now think.

When an AI notices a pattern, it stores it in a compressed way. Round objects are placed in a "roundness" direction, red objects in another direction for "redness," and so on. Maybe it notices "treeness" and "foodness" too. It abstracts out billions of directions, or patterns. Upon reflection—or training—it notices that the overlap of these four qualities produces "appleness," yet another direction. Furthermore, it links all these noticed directions with word patterns, which can also share overlapping qualities. So when a human requests a picture of an apple via the word "apple," the AI paints an image with those four (or more) qualities. It is not assembling bits of existing pictures; rather, it is "imagining" a new picture with the appropriate qualities. It sort of remembers a picture that does not exist but could.

This same technique can be used—in fact, is already being used, in very early forms—to find new drugs. The AI is trained

Sam Cannon, PHOTOGRAPHER

29.10: Withdrawal

"It wasn't able to render out a close replica of my cover—for now."

PROMPT: "A 3D rendering of a figure with its head in its hands being pierced with thousands of needles, octane, harsh light"





Patrick Savile, ILLUSTRATOR

30.06: A New Internet

"The image in my head turned out to be egg-based."

PROMPT: "Airbrush art, cracked egg, Japanese 70s design, surrealism, yves tanguy, koichi sato, magritte bunch of robots"





on a database of all the molecules we know to be active medicines, noticing patterns in their chemical structures. Then the AI is asked to "remember" or imagine molecules we have never thought of that seem to be similar to the molecules that work. Wonderfully, some of them actually do work, just as an AI image of a requested imaginary fruit can look remarkably like a fruit. This is the real transformation, and soon enough, the same technique will be used to help design automobiles, draft laws, write code, compose soundtracks, assemble worlds to entertain and instruct, and cocreate the stuff we do as work. We should take to heart the lessons we've learned so far from AI image generators, because there will soon be more pattern-seeking AIs in all realms of life. The panic cycle we presently face is simply a good rehearsal for the coming shift.

What we know about AI generators so far is that they work best as partners. The nightmare of a rogue AI taking over is just not happening. That vision is fundamentally a misreading of history. In the past, technology has rarely directly displaced humans from work they wanted to do. For instance, the automatic generation of pictures by a machine—called a camera—was feared in the 1800s because it would surely put portrait painters out of business. But the historian Hans Rooseboom could find only a *single* portrait painter from that time who felt unemployed by photography. (Photography actually inspired a resurgence of painting later in that century.) Closer to our time, we might have expected professional occupations in photography to fall as the smartphone swallowed the world and everybody became a photographer—with 95 million uploads to Instagram a day and counting. Yet the number of photography professionals in the US has been slowly rising, from 160,000 in 2002 (before camera phones) to 230,000 in 2021.

Instead of fearing AI, we are better served thinking about what it teaches us. And the most important thing AI image generators teach us is this: Creativity is not some supernatural force. It is something that can be synthesized, amplified, and manipulated. It turns out that we didn't need to achieve intelligence in order to hatch creativity. Creativity is more elemental than we thought. It is independent of consciousness. We can generate creativity in something as dumb as a deep-learning neural net. Massive data plus pattern-recognition algorithms seems sufficient to engineer a process that will surprise and aid us without ceasing.

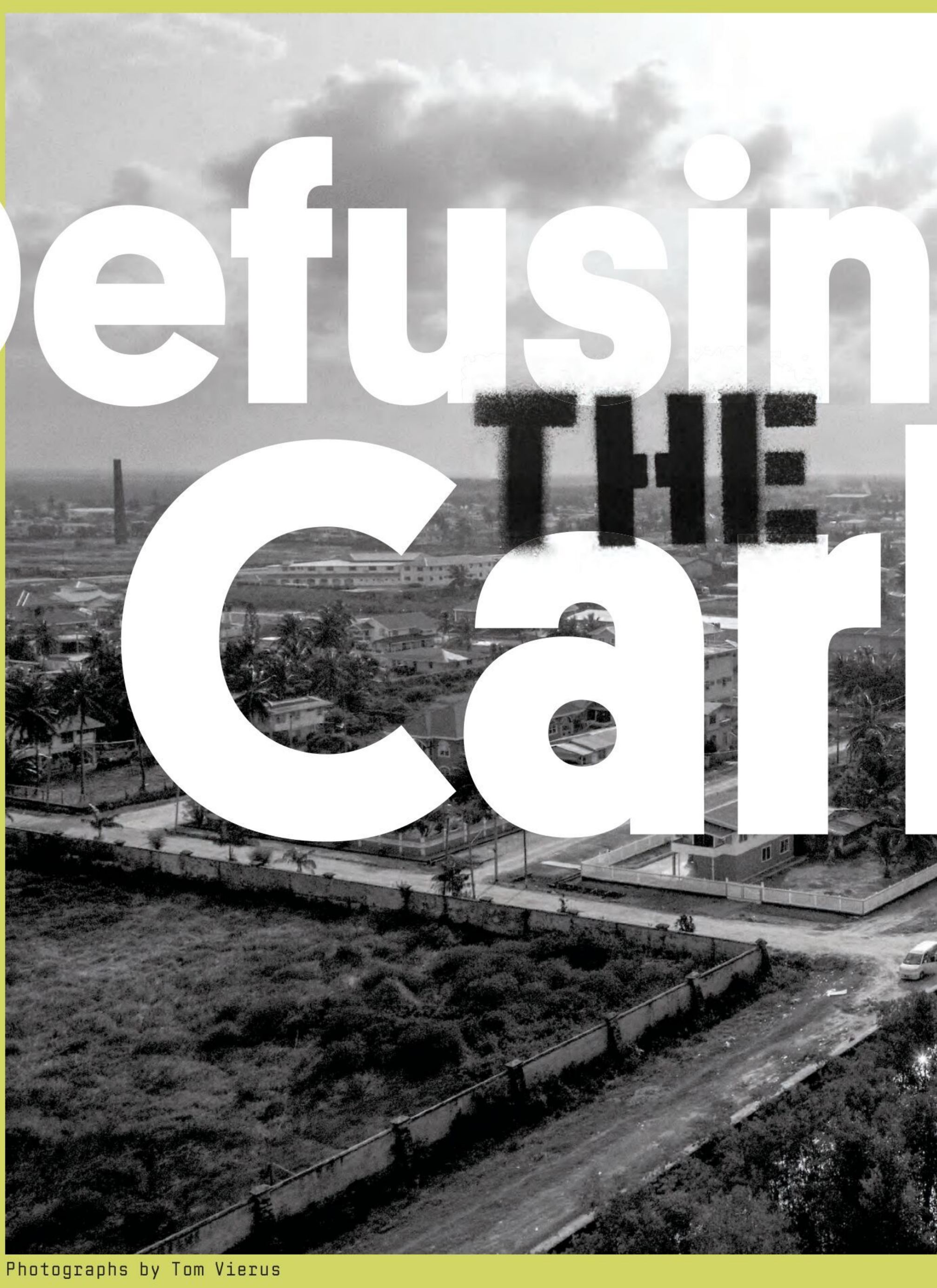
Scholars of creativity refer to something called Uppercase Creativity. Uppercase Creativity is the stunning, field-changing, world-altering rearrangement that a major breakthrough brings. Think special relativity, the discovery of DNA, or Picasso's *Guernica*. Uppercase Creativity goes beyond the merely new. It is special, and it is rare. It touches us humans in a profound way, far beyond what an alien AI can fathom.

To connect with a human deeply will always require a Creative human in the loop. This high creativity, however, should not be confused with the creativity that most human artists, designers, and inventors produce day-to-day. Mundane, ordinary, lowercase creativity is what we get with a great new logo design or a cool book cover, a nifty digital wearable or the latest must-have fashion, or the set design for our favorite sci-fi serial. Most human art, past and present, is lowercase. And lowercase creativity is exactly what the AI generators deliver.

But this is huge. For the first time in history, humans can conjure up everyday acts of creativity on demand, in real time, at scale, for cheap. Synthetic creativity is a commodity now. Ancient philosophers will turn in their graves, but it turns out that to make creativity—to generate something new—all you need is the right code. We can insert it into tiny devices that are presently inert, or we can apply creativity to large statistical models, or embed creativity in drug discovery routines. What else can we use synthetic creativity for? We may feel a little bit like medieval peasants who are being asked, "What would you do if you had the power of 250 horses at your fingertips?" We dunno. It's an extraordinary gift. What we do know is we now have easy engines of creativity, which we can aim into stale corners that have never seen novelty, innovation, or the wow of creative change. Against the background of everything that breaks down, this superpower can help us extend the wow indefinitely. Used properly, we can make a small dent in the universe.

OPEN AI/DALL-E2

Defusing the Caribbean



View of Georgetown, Guyana.

Photographs by Tom Vierus

Oil Bombs

Since 2015, Exxon has discovered 11 billion barrels of oil off the coast of Guyana. Now one lawyer is going up against the petroleum behemoth—and her own country—in a bid to stop the drilling before disaster strikes.

by Antonia Juhasz



IN LATE JUNE, inside a squat concrete building in Georgetown, Guyana, on a noisy street flanked by telephone repair shops and beauty supply stores, two lawyers were waging one of the most significant legal battles in the global fight against climate change. Melinda Janki and Ronald Burch-Smith sat in a ground-floor office staring intently at a computer screen, ignoring the sounds of macaws, monkeys, tree frogs, and traffic packing the streets, waiting to connect to the country's Supreme Court via Zoom. The internet is unreliable at best in Guyana's capital city, and the fear that it would choose today to conk out was palpable.

The two lawyers were a bit of an odd couple. Burch-Smith is tall and meticulous. Ask him if he knows the time and he's likely to answer "yes" rather than divulge the hour. Janki is a petite woman with warm eyes and a sharp wit, quickly moved to rigorous denouncements of injustice, from the war in Ukraine to the plight of the planet to the litter on the street. Burch-Smith has a framed *Phantom of the Opera* playbill above his desk. The art in Janki's office is a little more confrontational: a life-size painting of a fierce yellow jaguar that appears poised to step out of a blackened forest and straight through the picture frame. Together, the two attorneys have mounted a novel and audacious attack on Exxon Mobil, one of the world's largest corporations with the legal muscle to match.

In 2015, Exxon, which is known in Guyana as Esso, struck oil off the coast, the first significant find in the country's history. The scale of the discovery, 11 billion barrels so far, landed Guyana on the list of the world's top "carbon bombs"— fossil fuel projects capable of releasing more than a gigaton of carbon dioxide. Exxon ultimately plans to produce more than 1 million barrels of oil a day. That would transform Guyana—currently a carbon sink thanks to its dense blanket of rain forests and minimal emissions—into one of the world's top 20 oil producers by 2030. An Exxon Mobil spokesperson says that during the world's transition to cleaner energy, "we need two things at the same time: reduced emissions and a reliable source of energy. Exxon Mobil has a role to play in both." By 2027, Exxon expects its Guyana operations to have "about 30 percent lower greenhouse gas intensity" than its average oil or gas production. Climate experts estimate that 2030 is also the year by which much of Georgetown and coastal Guyana will be underwater as a result of unchecked global warming. Those living in the interior of the country will face the devastating impacts of worsening droughts and floods, from intensifying food insecurity to loss of land and homes. In 2021, Janki and Burch-Smith sued the Guyanese government for giving Exxon the green light. Exxon later joined the government as a codefendant in the case.

Georgetown's lush beauty—its neighborhoods teem with tropical flowers in scarlet reds, peacock blues, sun-kissed yellows, and turquoise greens—is made possible by its abundant sources of water: Rivers and canals carve paths through the streets, carrying water from the Amazon to the Atlantic, along whose coast most of the city—and 90 percent of the nation's population—resides. Viewed differently, though, the abundance of water is a sign of Georgetown's particular vulnerability to climate change. All around is the evidence of an impoverished city that is rapidly industrializing. Newly traffic-clogged streets strain to make room for horse-drawn carts; cows graze on street corners near Popeye's and KFC. Many homes and buildings have that beaten-down look common to places of either war or extreme weather.



TOM VIERUS FOR URGEWALD

With its lush forests, Guyana is a carbon sink. Exxon's project stands to make it a carbon bomb.

To call the groundbreaking lawsuit against Exxon a David-vs.-Goliath endeavor would be an understatement.

To call the Exxon lawsuit a David-versus-Goliath endeavor would be an understatement. When several US state attorneys general sued Exxon about five years ago for misleading investors and the public about the risks of climate change, a judge joked about the oil company, "Y'all have 300 lawyers on your side." Exxon then submitted more than 2 million pages of records to just one New York court. By contrast, Janki and Burch-Smith had one legal assistant. Janki has been known to stand in long lines at the court to file pleadings. She has also carted around enormous files filled with thousands of pages of material, which she reads without the assistance of a litigation team.

In the June hearing, Exxon was attempting to throw out virtually the entire testimony of one of Janki and Burch-Smith's clients on the grounds that he was not a climate scientist. When the judge appeared on the screen, he gave the pair more time to present their argument to keep the affidavit, which rests on key facts regarding fossil fuels and climate change, before the court.

Halting the project would deal Exxon a crippling blow; within eight years, Guyana is on track to become the company's single largest site of daily oil production. But it could also have implications for the global industry. Whereas climate lawsuits against fossil fuel companies have typically attempted to hold those corporations accountable for the harms of past operations, this one in Guyana seeks to force the company and the government to accept responsibility for the damage they will cause in the future. The case argues that oil development is fundamentally incompatible with human health and a sustainable environment. If successful, it could set an example for climate activists in other countries.

Kneecapping a global energy giant might sound like an impossible feat for two attorneys in a Global South nation with a population of less than 780,000 people. But they are wielding some powerful tools. Guyana happens to have some of the most robust environmental protections in the world. Its constitution contains provisions that explicitly protect the rights of citizens—present and future—to a healthy environment. "Virtually every aspect of this operation is in violation of Guyana's constitution, and the right to a healthy environment, and the right of sustainable development, and the rights of future generations," explains Carroll Muffett, the president and CEO of the Center for International Environmental Law. "And from that arise serious consequences in terms of how the government must respond."

"The provisions are groundbreaking," Janki says. She should know—30 years ago, she helped author them. Plus, Janki's knowledge on the matter has still another layer: Early in her career she spent four years working for the oil giant British Petroleum, now known as BP.

Melinda Janki's visionary work introduced the concept of natural capital to Guyanese law—and challenged the dominance of gross domestic product.

JANKI GREW UP in Georgetown, in a house close enough to the Atlantic Ocean for the sounds of waves to lull her to sleep each night. Much of her childhood was spent outdoors, where she developed an affinity for the water and the forest. When she was 5, a small brown dog appeared on the front porch in the bright rays of the early morning sun. Janki was reading a book of Christian fables at the time, so she named her first beloved pet Lucifer, Son of the Morning. "The story ends very badly," she recalled. "He must have gotten out and been on the road outside the house, and someone knocked him down and killed him." Janki was crushed—and furious. "It taught me the lesson that life is tenuous," she says, and also "to fight for the little underdogs." She would go on to care for dozens of stray animals, including dogs, donkeys, cats, horses, wild birds, and a baby giant otter.

Janki's family left Guyana in the 1970s, when she was 12 years old and the country was in a period of intense political instability. After living in Zambia and Trinidad, Janki eventually settled in London. She studied law at Oxford and University College London, focusing on human rights, environmental and economic law, and intellectual property. She began her career at one of Britain's premier corporate law firms, Lovell, White, & King—"otherwise known as 'Lovely, White, and Clean,'" Janki quips—where she recalled being one of the first non-white trainees. She left the firm in 1989 to become an in-house lawyer at BP's world headquarters. Janki doesn't speak negatively about her experiences working there, but over time her growing condemnation of the industry has come to dominate both her life and work.

It didn't take long for the shine of London to wear off. On the 30th floor of a skyscraper, Janki felt entirely cut off from nature. Her life started to seem all too comfortable. "You know, comfort is a form of suicide," she says. After four years absorbing the inner workings of the oil industry, she decided to leave. Janki returned to Georgetown in 1994, a time when her homeland seemed brimming with promise. "Your heart tells you what you should be doing, and it just tugged me back to Guyana," she says.

GUYANA'S NAME IS said to derive from an Indigenous word for "land of many waters." The largest of the country's rivers, the Essequibo, begins at the Acarai Mountains near the Brazilian border and flows north through forest and savanna, cutting a straight line for 630 miles across the length of the country. As the Essequibo makes its way to the coast, it's joined by tributaries of the Amazon, Rupununi, Mazaruni, and Cuyuni rivers, all carrying a rich bounty of sediment filled with nutrients. Guyana's ocean contains some of the highest recorded levels of chlorophyll biomass in the world. In turn, the waters are home to more than 900 species of fish, essential to both local subsistence and the Guyanese economy. There are also dolphins, manta rays, sperm whales, and six kinds of marine turtles, some of which are endangered.

In the interior, nestled between forests, picturesque mountains, tributaries of the Amazon, and the headwaters of the Rupununi river, rests the virtually untouched savanna that the Wapishana and Macushi call home. They are among the nine tribes collectively referred to as Amerindians, who have lived in and around present-day Guyana for millennia. Most live subsistence lifestyles based on hunting, fishing, and farming, not all that different from those of their ancestors.

For centuries, a rotating list of foreign powers extracted Guyana's natural resources and returned the products and profits to their home ports. In 1667, to secure their claim on Guyana, the Dutch traded parts of modern-day New York and New Jersey to the British. The Dutch enslaved Africans to work the sugarcane fields and pushed many Indigenous peoples into the interior to give themselves easy access to the sea. Almost two centuries later, Britain took Guyana by force. It became one of the

empire's most lucrative colonies, powered first by slavery and then the indentured servitude of people from India, China, and Portugal. An 1823 rebellion led by enslaved people in Guyana is credited with contributing to the eventual abolition of slavery across the entire British Empire; in 1917, people in indentured servitude in Guyana successfully organized to force an end to that practice as well. In the 20th century, American corporations came to Guyana, mining for bauxite and gold. By the 1950s, they also hunted for oil, but decades of effort proved largely futile.

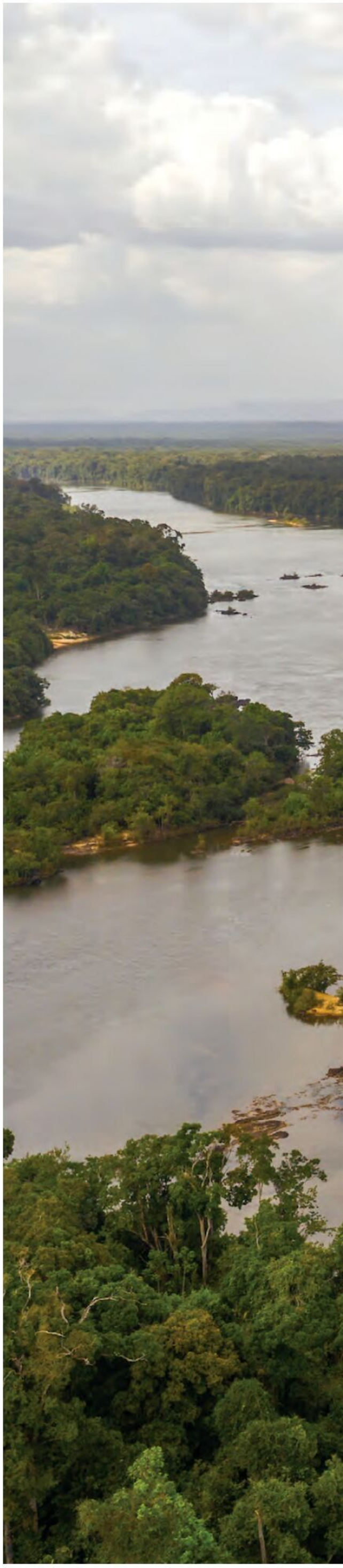
In 1992, Guyana held its first free and fair democratic election in decades. The new government, led by the leftist People's Progressive Party, was eager to protect the country's natural resources after centuries of colonial exploitation, and it saw environmental protection as part of a broader mission to secure social justice. At the time, Janki had just returned and been admitted to the national bar. She had no party affiliation or political connections. She was, she says, a "nobody." But, in 1995, when Janki learned that the nation's first-ever environmental laws were going to be drafted at an invitation-only conference, she knew she had to be there. A partner at the law firm where she worked was also the owner of one of Guyana's two national newspapers, and he helped Janki finagle a press pass.

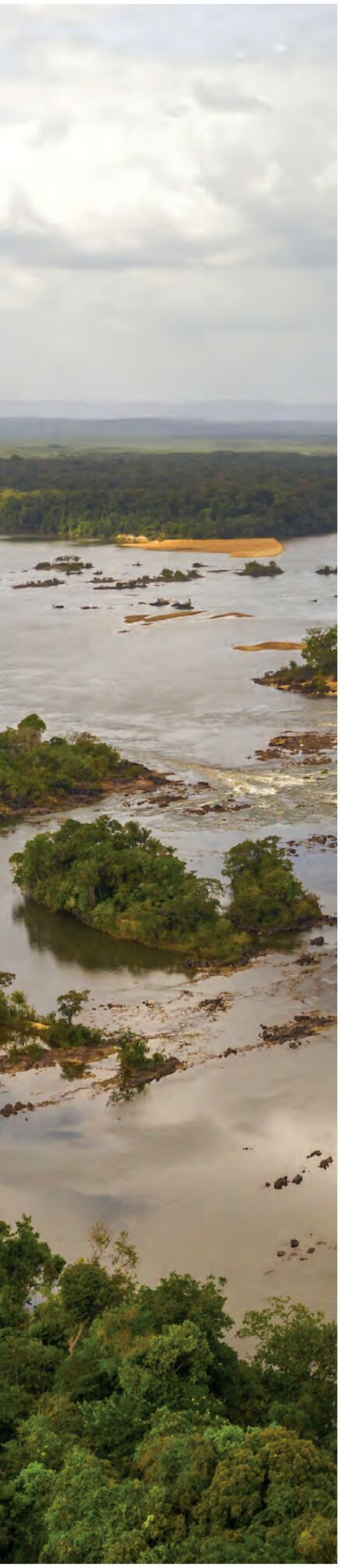
The conference was held at the Pegasus Hotel, a seven-story cylinder of blue glass and white steel that towers above Georgetown. No press accounts of the event can be found, and many of the participants have since died, but Janki recalls that there were about 100 attendees, most of them men, who droned through a series of forgettable presentations. What did catch her attention was the draft Environmental Protection Act. "When I got a look at what they were writing, I was absolutely horrified," she says. In her view, the legislation was far too weak.

During a coffee break, Janki spied a special adviser to the president, Lakeram Chatarpaul, standing alone outside of the conference room. Janki was a lot shier then, she says, but in her recollection she "lobbied like mad and made quite a nuisance of myself." Chatarpaul invited her to write to him. What she wrote worked: After he read her ideas, Janki was hired by the Inter-American Development Bank to draft the new law for the government.

Over many months, Janki adapted what she felt were the most robust environmental laws from around the world and "put in a raft of new provisions," she says. She included the "polluter pays" and "precautionary" principles, which hold companies liable for the costs of cleaning up pollution and the government responsible for implementing measures to prevent environmental harm, even in the absence of "full scientific certainty." Importantly, Janki defined the "environment" to include, among other things, the atmosphere and climate. "This was in 1995, when people were relatively unconcerned about greenhouse gas pollution, and the carbon majors were misleading people," she says. She imbued the Environmental Protection Agency with significant authority, including the requirement that any proposed project, from mining to construction, had to include a detailed environmental impact assessment. If the assessments were found to be lacking, the EPA would have the power to reject projects outright, as well as the ability to put conditions into permits to ensure that the company's operations did not conflict with Guyana's international human-rights and environmental obligations. She also included far-reaching provisions for public access to information, participation, oversight, and compensation for harm, plus some other "visionary stuff in the act that nobody noticed."

One striking example of "visionary stuff" was the introduction of the concept of natural capital into Guyanese law. Each year, the EPA is required to take a full accounting of the nation's ecosystem—from wildlife to vegetation—and make it publicly available. This creates a baseline from which to measure both ecosystem value and potential harm. Natural capital is a direct challenge to gross domestic product, or how much a country produces, consumes, and exports—the prevailing measure for assessing a nation's economic health. A rising GDP is often considered inherently positive, regardless of the human or environmental costs. When a forest is clear-cut, for instance, GDP increases due to the labor and machinery used and the timber sold. Natural capital, by contrast, considers the value of the trees to the climate, the animal species, and the people who call the forest home. Under this model, the forest's destruction is a cost and its protection a benefit. While Janki's law doesn't require this entire calculation, simply introducing the concept was a significant step, which several other nations, including Botswana, Colombia, and Egypt, have since embraced.





In 1995, cyanide-filled mining waste spilled into the Essequibo River, killing fish and other animals and polluting the cropland on which Amerindian communities relied. The spill and others like it were attributed to a lack of meaningful environmental regulation, and they galvanized the nation to support the Environmental Protection Act, which was signed into law on June 5, 1996.

Two years later, the government turned to rewriting its constitution and solicited public submissions. Seizing the opportunity to embed strong environmental protections within the constitution itself, Janki wrote what she has described as "a statement of the obvious" that was ultimately included in the preamble: "The well-being for the nation depends upon preserving clean air, fertile soils, pure water, and the rich diversity of plants, animals, and ecosystems."

But it was the provisions that Janki lobbied to be included in the text of the constitution that were the most significant. Drawn largely from South Africa's new postapartheid constitution, they conferred upon every Guyanese citizen "the right to an environment that is not harmful to his or her health or well-being" and would hold the state responsible for protecting the environment for the benefit of present and future generations. They also required the courts to "pay due regard to international law, international conventions, covenants, and charters bearing on human rights." These include human-rights obligations to clean air and water, life, and livelihoods. Taken together, these constitutional provisions are far stronger than the environmental protections found in most northern nations, including the US. "I don't want to sound as if I am showing off," says Janki, "but, really, it is all there."

A few years later, an Arecuna tribal leader from the Upper Mazaruni area came to Janki's law office seeking help to confront continued abuse from the mining industry. Janki turned her attention to building and securing the rights of these communities. She also worked as a consultant in drafting the 2006 Amerindian Act, providing for collective rights to land, natural resources, and self-determination. In academic and legal journals, she made the case that failing to fulfill human-rights obligations to life, health, water, food, nondiscrimination, and self-determination, including the rights of local communities to consent to policies and programs that directly affect them, "can be a trigger for environmental destruction." She also contributed to the drafting of the Escazu Agreement, the first regional environmental treaty of Latin America and the Caribbean (ratified by 14 nations but open to all 33), "contributing to the protection of the right of every person of present and future generations to live in a healthy environment and to sustainable development."

Janki had expected that when the time came, Guyana's government and citizenry would make use of the strong legal foundation she had helped build. She would soon learn that, at least when it came to oil, she was wrong.

In March 2015, the Deepwater Champion rig was at work for Exxon Mobil, exploring for oil in the Atlantic Ocean 120 miles off the coast of Guyana, drilling below 6,000 feet of water and through 12,000 feet of earth. Ultra-deepwater drilling is so complex that experts liken it to space travel, and the dangers are well known. Five years earlier, the Deepwater Horizon rig was at work for BP when it exploded in the Gulf of Mexico, killing 11 workers and setting off the worst offshore oil spill in history. (The rig in Guyana was owned and operated by the same company, Transocean, that ran the rig in the Gulf.)

Only two months after it began exploring, Exxon struck oil. The first significant find in Guyana's history came as a shock. Exxon Mobil's then CEO, Rex Tillerson, told shareholders it was the largest oil find anywhere in the world that year. The Guyanese government, led by President David Granger of the People's National Congress Reform, quickly signed a contract with Exxon and awarded the company a series of 23-year permits—which were at the time withheld from the public. When production began four years later ("a fraction of the time it usually takes," according to Exxon spokesperson Meghan



Guyana's waters sustain over 900 species of fish, essential to local subsistence and the economy.

MacDonald), Guyana was officially ushered into the exclusive club of oil-producing nations. President Granger proclaimed it National Petroleum Day and said the discovery would transform the country's economic development and ensure a "good life" for all.

The People's Progressive Party, led by Bharrat Jagdeo, accused Granger of signing a one-sided deal with Exxon in exchange "for peanuts." Industry analysts have found that the government is receiving a below-average return on Exxon's projects. Exxon will recoup all of its expenses, including all development and operating expenses, out of the oil it extracts, leaving the government and public to largely absorb the company's costs. For every barrel of oil produced, until it recovers its costs, Exxon receives 85.5 percent of the value of the oil compared to Guyana's 14.5 percent, according to the Institute for Energy Economics and Financial Analysis.

Exxon maintains that the contract terms are competitive and that it "provides a structure and terms that are equitable to both the government and investing companies, commensurate with the risk associated with each project."

Janki, meanwhile, set her sights on scuttling the entire Exxon operation in Guyana. "At that moment nobody else was willing to challenge what the oil sector was doing," Janki says. In 2018, she realized she would have to go to court.

Janki filed a suit, based on the Environmental Protection Act, arguing that the government had acted illegally by granting production licenses to the two companies that Exxon is partnering with, as they had not filed their own environmental impact assessments. The judge ruled that the license granted to Exxon was sufficient, but Janki was not dissuaded. She began giving talks and lectures, arguing that there were grounds to challenge Exxon's operations, and she soon found a kindred spirit in Troy Thomas, who was then president of the Transparency Institute, the nation's leading anti-corruption organization. In time, he would become one of her most important collaborators.

When Exxon started operating in Guyana, Thomas, like Janki, worried that the corrupting force of oil money would threaten the country's meager political gains of the past few years—the dreaded "oil curse." Countries that depend on exporting oil are among the most economically troubled, authoritarian, and conflict-ridden nations in the world. Terry Lynn Karl, a professor at Stanford University, documents how, in the

Janki expected Guyana to make use of the environmental protections she instituted. When it came to oil, she was wrong.



Heavy rainfall in Guyana is nothing new. But now the rainy seasons are longer and wetter, and the dry seasons are hotter, with intensifying drought.

“I don’t see how we can agree to kill ourselves,” Troy Thomas says about Guyana’s decision to drill for oil.

past 40 years, the consequences of becoming oil-rich—far from the promise it offers—have tended to be more destructive than positive. Thomas was well aware of this, as well as of the growing efforts worldwide to shift away from fossil fuels altogether. “We know that petroleum is a dead end,” he says.

Globally, as of 2015, the fossil fuel industry and its products accounted for 91 percent of all industrial greenhouse gas emissions, and about 70 percent of all anthropogenic greenhouse emissions. Since 1988, more than half of all global industrial greenhouse emissions can be traced to just 25 fossil fuel companies. Exxon Mobil is number five on the list compiled by the CDP Carbon Majors Database.

Thomas grew up on Wakenaam, an island with a distinctly Caribbean feel that’s just a short boat ride from Georgetown. His father was a small farmer like most of the island’s inhabitants, growing crops like plantains, cassava, and tubers. Wakenaam is surrounded by a seawall built by the Dutch to keep the water out. But “wall” seems too generous a word for the roughly 4-foot-high crumbling ledge. It worked for a time, but the sea has been rising, and the storms are now worse, regularly inundating the island’s homes and fields. “The ocean just has to decide one day: ‘I’m going to be disruptive.’ And that’s it for the island of Wakenaam,” Thomas says. “It’s not a theoretical, conceptual argument. It’s right now.” It didn’t make any sense to him that the government actively welcomed a project whose massive emissions contributed to the sea-level rise that threatened his own family’s very survival. “I don’t see how we can agree to kill ourselves,” he says.

Thomas, who often wears a dress shirt and blazer, with his hair in a loose ponytail of shoulder-length dreadlocks, is a professor of natural sciences at the University of Guyana. As a father of two young children, balancing family, work, and a political activism that is rare in this small nation, Thomas usually gets no more than a few hours of sleep each night. He understands why many, if not most, people in Guyana find it difficult to speak out against the government and its major partners. Guyana’s political history has a violent side, including the assassinations of famed anti-colonial scholar and political activist Walter Rodney and one of the nation’s agricultural ministers. Political and economic retribution can also be vicious, instilling fear and limiting action, Thomas explains.

Thomas’ organization succeeded in making Exxon’s contract with the government public in late 2017, an effort that brought him into conversation with Janki. Thomas felt he had reached the limitations of traditional advocacy to stop Exxon, and he was intrigued by Janki’s novel, but potent, legal approach. He decided to join forces with her.

In May 2020, Janki filed a new suit against the government on Thomas’ behalf. She argued that the 23-year permits violated the Environmental Protection Act, which stipulates that the government may grant only five-year leases for oil drilling. In a settlement, the EPA agreed to reduce the terms to five years, after which Exxon would need to reapply for new permits. This was a major victory, but it didn’t address the roots of Thomas’ deeper concerns: the increasingly existential threat of climate change.

And so, emboldened by their success, Thomas and Janki began to lay the groundwork for an even more ambitious case against Exxon, which others would soon join.

QUADAD DEFREITAS IS Janki's second client in the pending case against Exxon. The 23-year-old with boy-band good looks is Wapishana and grew up in the Rupununi region in southwest Guyana, near the border with Brazil. As a child, he split his time between the village of Katoonerib, where he attended primary school, and the cattle ranch where his family worked. Among its limited modern attributes, the ranch has used solar panels for decades. DeFreitas works on conservation efforts in the region. "There are so many animals!" he says effusively. "Birds, otters, monkeys, caiman, jaguars—you cannot list them all!"

Today, his family has a small cattle ranch and a budding ecotourism business of its own. But DeFreitas worries that the already devastating effects of climate change threaten not only his family's businesses but the future of his 4-year-old brother—and his ability to call the Rupununi home.

Heavy rainfall in Guyana is nothing new. "People live on the land, they know where the water usually comes, and they plan their farms and houses because of that knowledge," DeFreitas explains. But now the rainy seasons are longer and wetter, and the dry seasons are hotter, with intensifying drought. All year round, the weather is unpredictable, and it's getting worse. Wells and ponds are running dry, leaving families without drinking water or fish to eat; the river both swells and dries out well beyond the norm; and floods increasingly destroy crops and villages.

One rainy day, I visited a small plot of land in Katoonerib near DeFreitas' primary school. Huts made of brown earth and thatched roofs hand-stitched from tree fronds dotted the horizon. A farmer removed an ear of corn from the stalk and, with the deft precision that comes from decades of repetition, swiftly pulled back on the skin to reveal its rotting insides. A waterlogged crop is unable to bear fruit. And it wasn't only the corn that was ruined, but the cassava, papaya, yams, pineapple, peanuts, and pumpkins—all of the food grown on the farm.

As Janki built her third case against Exxon, DeFreitas became an eager participant. Pointing to the benefits of solar power and the minimal use of fossil fuels in his community, he knows that other, less harmful ways of producing energy are possible. Beyond this he looks at the implications of exacerbating the climate crisis and considers Exxon's operations not only crazy but wrong. "I just don't see the point," he says.

In May 2021, with Thomas and DeFreitas as plaintiffs, Janki, joined by Burch-Smith, filed the landmark suit against the government and Exxon. "The earth's atmosphere and oceans have been and continue to be polluted by the release and accumulation of greenhouse gases," the lawyers state, resulting from "the production, transportation, refining and use of fossil fuels." Therefore, the government's approval of Exxon's operations, they argue, violates the constitutional right of current and future Guyanese citizens to an environment that is not harmful to their health or well-being. It is the first case in which this provision has been litigated.

Thomas' affidavit, which says that the "existential threat" caused by greenhouse gas emissions is already harming the health and well-being of the Guyanese people, is the one Exxon is trying to get thrown out. "The intensity of that harm will increase as fossil fuels continue to be burned," Thomas writes, placing responsibility on the government and Exxon by noting that combustion is "the intended and foreseeable consequence of producing that oil and gas." Thomas quotes extensively from Exxon's own 1982 research, which concluded that "mitigation of the 'greenhouse effect' would require major reductions in fossil fuel combustion." But because Thomas isn't a climate scientist, Exxon argues that his statements reflect opinion rather than agreed-upon facts.





They're "not going to concede anything about climate change unless they have a gun to their head, metaphorically," Burch-Smith said about Exxon.

Scholars agree that Janki's lawsuits are creating innovative precedents for challenging the major contributors to climate change. Joana Setzer, an assistant professor at the Grantham Research Institute on Climate Change and the Environment at the London School of Economics, credits the case for advancing human-rights-based climate litigation, uniquely challenging the permitting of new oil reserves based on the harms of the resulting emissions. "If the case is successful, it could inspire similar lawsuits in other countries," she says. "It's a real human rights case."

Exxon contends that it "has complied with all applicable laws at every step of the exploration, appraisal, development and production stages" in response to questions about the suit.

In September 2021, Exxon joined the government as a codefendant, which suggests it wasn't content to let the case play out without its influence. The multinational argues that the plaintiffs have "misconceived" the Environmental Protection Act, noting that the government approved the environmental impact assessments necessary for drilling to proceed. Exxon also says the plaintiffs "mischaracterized" the constitutional provision on which Janki and Burch-Smith have built their case. Although that provision requires the state to "secure sustainable development and use of natural resources," it goes on to say that it must do this "while promoting justifiable economic and social development."

The government's response follows a similar argument. It affirms that it approved Exxon's environmental impact assessment and cites the same constitutional provision noted by Exxon. Preventing Guyana from developing its petroleum resources, the government argues, would bring "unwarranted economic and social costs." Bharrat Jagdeo, once the country's president and now its vice president, has argued that Guyana should pump its oil quickly, while it still has the chance. (He has emerged as a leader of a group of government officials in places like Suriname and Ghana who are making the same case.) Jagdeo, President Irfaan Ali, and other government officials declined repeated requests for interviews.

The government and Exxon's economic prosperity argument was dealt a blow in October 2021. The Biden administration, following a new US directive to "promote ending international financing of carbon-intensive fossil fuel-based energy," blocked a $180 million loan from the Inter-American Development Bank to a private Guyanese company that was meant to support the expansion of Exxon's onshore facilities.

If economic prosperity is the goal, the oil project is not off to a good start. Despite three years of production, Guyana remains a struggling nation with one of the highest poverty rates in Latin America and the Caribbean. The lure of a windfall from oil is understandably tempting. And money from oil has flowed into the country, but measuring its impact is difficult. The World Bank says that "extraordinary economic growth of 20–40 percent over the last two years brought GDP per capita to over $9,300 in 2021, from about $6,600 in 2019." But GDP remains a questionable metric, in that it entirely ignores very real environmental costs, and those per capita figures merely divide a national value by the population—with no consideration for unequal distribution of the gains.

Exxon spokesperson Meghan MacDonald emphasized the company's efforts to add to Guyana's workforce, noting that there are more than 4,400 Guyanese workers supporting Exxon Mobil's activities there. "In frontier countries around the world, it takes some time to develop the workforce to handle the operations in a complex, highly volatile work environment," MacDonald said. It's widely known, though, that the oil and gas industry is increasingly automated and less reliant on workers—something that Exxon itself acknowledged in a statement on its website that has since been deleted.

By the end of 2021, Exxon and its partners had taken in six times more revenue from its oil operations in Guyana than the government had—$3.6 billion to the government's $607 million—according to the Institute for Energy Economics and Financial Analysis. Due to the lopsided contact, the group estimates that by 2027, Guyana will carry a liability of more than $34 billion owed to Exxon and its partners to cover their development and related costs. "There isn't going to be a vast amount of wealth," Janki says. "There is going to be, most likely, an enormous bill that the Guyanese people will be saddled with."

If the court agrees with Janki that this oil operation is incompatible with the right to a healthy environment, then the government has to decide whether to stop the activity or somehow find a way to make it not violate the constitution. That may be an impossible feat, as the government might have to prove that oil production would not result in a worsening of global warming. The government may also be obliged to forgo any new authorizations for oil operations or revoke Exxon's existing licenses. Oil drilling in Guyana could even be ended entirely if it is impossible for the government to issue permits without violating the law.

"Were the court to agree that this development is in violation of the Guyanese constitution, that is obviously an extraordinarily significant find-

ing, and it would have enormous impacts on any future development of oil in Guyana," says Muffett of the Center for International Environmental Law. "Losing access to Guyana as a result of the groundbreaking legal action there would be yet another signal that the company's core business model is fundamentally incompatible with confronting the climate crisis. Given the huge prominence of Guyana in Exxon's portfolio, investors are likely to listen."

Seated at a table at the Marriott Hotel in June, Burch-Smith talked about the case with me. The American hotel chain, where rooms cost upwards of $300 a night, has recently supplanted the Pegasus as the "place to be" in Georgetown. Burch-Smith spoke quietly, careful not to be overheard by the people at nearby tables and frolicking loudly in the pool. Many of them had Texas accents. He surmised that more Americans will be coming to the country as Exxon's operations continue to expand.

"The fundamental problem is that the only way you're going to slow climate change is to stop burning oil." Exxon can't challenge that, Burch-Smith almost whispers.



Part of the sea wall that was built to protect the areas east of Georgetown, Guyana.

WIN OR LOSE, Janki's efforts and the case are already having an impact. Under a blazing midday sun in June, on the eve of the court hearing, roughly 25 men and women gathered outside of Exxon's onshore base in Georgetown to protest the company's operations—a rare, but increasingly frequent, occurrence. The protesters fanned out along the edge of the congested four-lane highway, holding white placards with handwritten messages: "Slavery was abolished centuries ago." "Stop raping our country." "Exxon make mo money than God & Guyana gets nothing."

In July, 23 years after Janki wrote it into Guyana's constitution, the United Nations General Assembly recognized the right to a clean, healthy, and sustainable environment as a fundamental human right guaranteed to all. That has opened the door for people in any UN signatory nation to follow Janki's lead and challenge fossil fuel operations in court by making the case that they are incompatible with these newly enshrined rights.

In September, Exxon reported a 42-gallon oil spill from a production rig, stretching 13 miles across the Atlantic. It was minor and, the company says, was isolated the following day. But such spills are common in offshore oil production, and fears of a spill large enough to have a catastrophic effect on the marine ecosystem loom large here. "If something should go wrong out there, it definitely would affect not just livelihoods but the entire economy," warns Sopheia Edghill, a marine conservationist at the University of Guyana.

During the hearing, the judge announced his retirement from the court, and he has yet to be replaced. Janki was also recently faced with another challenge. Burch-Smith withdrew as her co-counsel, citing "some differences in certain technical aspects." But for Janki, there is no withdrawal. She will continue arguing the case on behalf of Thomas and DeFreitas, and she has a new legal partner to help her. The case will move forward when a new judge is assigned. And if it fails to stop Exxon, she has filed three other cases against the government and Exxon. "This isn't a story of powerlessness; it's a story of power," Janki says. "This is the biggest climate change case in the world."

"This isn't a story of powerlessness; it's a story of power," Janki says.

ANTONIA JUHASZ *is an award-winning investigative journalist and author who reports from the front lines of fossil fuels, conflict, and the climate crisis.*

CRYPTO KEEPER KEK

by Steven Levy

Photographs by Julien Faure



iPod mastermind Tony Fadell made Ledger's new hardware wallet—a tiny vault for digital cash—flashy and fun. Plus, with this gadget you'll never get FTX'd.

ASTIC LOGIC
L1008010ZB

WHEN I COME TO PARIS

Tony Fadell hangs out in the Donjon, Ledger's in-house security lab.

TO SEE TONY FADELL'S NEW device, a clean rain has washed the city and the sun is out. Fadell and I hail a taxi. When he gives the address for Ledger—a maker of hardware wallets for the cryptoverse—he speaks in French, but even after six years abroad, there's still Detroit in his voice.

At the meeting we enter, everyone is speaking English. People are sitting at a large table. On the walls are labels such as PHOTO ASSETS, VIEW FROM LANDING PAGE, USER FLOW, with big printouts taped below. Fadell strides to the front of the room.

"We've got seven weeks to pull this off," he says. *"Are we going to pull this off?"*

The people in the room say yes, they will pull it off. They sound confident, weary, but ready for the next round of work. Each person says what they have done since the last time they met. Fadell responds with questions. *What's the drop-dead date on the plastic blanks? Where's the press release? Are we recording the click-click-click? I want to hear it!*

The click remark reminds everyone, as if they needed it, that Fadell once led the team at Apple that created the iPod, with its elegant clicky wheel and revolutionary interface. He also cofounded Nest and created its smart thermostat, which Google then acquired.

Fadell circles the room to examine the printouts, which describe the product rollout. A man with a video camera follows him, recording the moment for posterity and promotional use.

Fadell stops to examine a group of photos of the device: a hardware wallet called Ledger Stax. This gadget is a utilitarian thing. It's a physical lock for digital secrets. When you own cryptocurrency, your balance is protected solely by a private key that can be devilishly hard to keep safe. Ledger's wallets, made of steel and silicon (and, OK, plastic), act as tiny vaults, but so far they have been off-putting. Much like crypto itself. Fadell is reinventing this device, his first major design project in years. He has come to believe that by giving it the panache of the hottest consumer gadgets, he will redirect the crypto field, just as he helped kick off digital music and the smart home.

Fadell looks at photos of the credit-card-sized wallet and its innovative E Ink touchscreen. Ledger is pricing the item at $279. That's a rounding error for those who buy Bored Apes. To add a bit of flair, the screen wraps around one side, giving it the equivalent of the spine on a book. But the photo doesn't show off the bend enough. "It's very rectilinear and 2D," he says. "Not enough spine. I'm not feeling the curve." He frowns. "And it's so dark."

David Sloo, a user experience designer who worked with Fadell at Nest, picks up on the critique. "Can we be less Darth Vader and more Rebel?"

Fadell agrees. "It's really who we are—it's all about the Empire."

His remark is a segue to the next panel, marked "MANIFESTO." A handful of slogans are taped to the glass.

Crypto is the new money.

Security is a human right.

Welcome to a new era of financial freedom.

The first touchscreen device made to protect your most valuable assets.

Fadell looks hardest at one that reads:

In [L] Stax We Trust.

He is not satisfied with the prominence of the [L], the Ledger logo, which appears in a custom military-style typeface. The brand is what people should remember. "In five years, every time you see that L you'll think *Ledger*," he says. "Like the Apple logo stands for the brand."

The comparison seems absurd. The company is nowhere near that size, its product is alien to most Earthlings, and its niche—crypto—has been undergoing months of shock treatment. Fadell seems unfazed.

"It's coming together," he says. "Forty-nine days!"

During those 49 days, the arc of crypto will bend into a dunk tank. Timing, as product gurus know, is everything. Stax might be coming at the perfect moment. It could as easily be the worst.



LEDGER WAS FOUNDED IN 2014 BY members of a tech collective called La Maison du Bitcoin. They wanted to build a wallet for crypto purists. These people would never leave their private keys on a phone or laptop—too hackable—or park their holdings in an exchange, which is a trusted, centralized institution and no better than a bank. ("Trust" is a pejorative in this world.) That was the year thousands of people lost their investments in a hack of crypto's flagship exchange, Mt. Gox, wiping out many customers' life savings.

Ledger's savvy consumers would entrust their keys only to a hardware wallet, something they could hold in their hands even when servers went down and exchanges went bust. You'd begin a transaction on a phone or laptop and use the wallet to verify it. Your private key, marooned on its Alcatraz, would never cross the gap to those less secure devices.

The company's first wallet, released late that year, was nothing special. But it satisfied a need among some crypto folk. Subsequent models got tiny displays. Ledger ultimately sold more than 5 million of its wallets, which it says now secure 20 percent of the world's crypto and more than 30 percent of NFTs. True believers wear Ledger wallets around their necks.



By 2018, however, the crypto market had plunged into one of its cold spells, and Ledger's sales were flat. An early investor named Pascal Gauthier came to believe that a fusty mentality was hindering the company's growth. "The French engineer decides everything, which is why the French always come up with innovations, but we're shitty at taking them to market and making it a business," he says. He became part of a boardroom uprising that put him in charge.

Gauthier, who had worked in ad tech (first at Yahoo and then as COO of a successful French company called Criteo), wanted Ledger to go from selling to the "B to G" market—business to geek—to appealing to the wider, nontechnical world. He wanted to mix Ledger's rigid security focus with the verve of Steve Jobs–level creativity. "Maybe it's delusional," says Gauthier, who dresses as if awaiting a Sun Valley invitation, in an ever-present black Patagonia vest. "But I want to build things at scale, to build a company in Europe that will compete with Apple, Google."

He felt Ledger needed to shake off a bit of its Frenchness. "If you want marketing and sales, you need Americans," he says. "There is no other way."

Gauthier started by wooing an expatriate he'd befriended. Ian Rogers is an Iggy Pop-ish 50-year-old with long blond hair, tattoos on his fingers, and a résumé loaded with trophy jobs, albeit trophies seldom found in the same case. He played in a high school band called Albino K-Mart Shoppers, was webmaster for the Beastie Boys, CEO of Beats Music, cofounder of Apple Music, and digital czar of the luxury-brand juggernaut LVMH, a gig that brought him to the City of Lights.

By 2020, though, he was open to Gauthier's pitch. He'd long been interested in crypto, having read the foundational Satoshi paper in 2009. Gauthier was offering him a chance to participate in what he regarded as a nascent revolution of ownership, anchored by the Gibraltar-like certainty of cryptographic private keys. "We know this technology will matter in the future, because a lot of humanity, if not all of humanity, will own digital items," he says. "It's just like it was in 2008, when people said not everyone would have a smartphone."

He also respected the business model—Ledger sold actual devices, not dicey promises of perpetually rising markets. For him, private wallets embodied the decentralized ethos at

the core of the crypto vision. "The people at this company wouldn't work at Coinbase," Rogers says. "They don't want to work at a bank. They believe in self-custody."

Still, Rogers wanted to do his due diligence. Fadell, a parent friend from his children's school in Paris, took it upon himself to investigate. At that point Fadell was living a quiet life as an investor. During the first months of the pandemic it was a super quiet life. "Tony never crossed the fucking transom of his door," Rogers says. Fadell was busy giving product advice to the companies he funded and writing a business book that drew on his career, a pursuit usually signifying a career's end. But Rogers had gotten him curious, so he took a hard look at what the company considered its biggest strength—its security.

Fadell's guide to Ledger's operations was its chief technology officer, Charles Guillemet, who joined the company in 2017. Inside its headquarters, behind a giant medieval-style door off a Paris lane, Guillemet created the Donjon, a jacked-up security lab that verifies the resilience of every aspect of the hardware, down to the chip circuits. Inside the Donjon, motherboards get probed as if in a 21st-century version of Frankenstein's lab. Lasers connected to oven-sized oscilloscopes poke at chips to observe how they might fail. Guillemet told Fadell he was appalled at the idea of people securing their assets on laptops or iPhones, which he deemed hopelessly vulnerable. He despised fingerprints and facial recognition. Your biometrics are public, after all, and can be counterfeited.

The more time Fadell spent with Guillemet and the Ledger team, the more convinced he became. "I didn't believe in all that crypto hype, but I believe in the technology," he says. He told Rogers that Ledger was the real deal. Rogers became the company's chief experience officer in January 2021, and later that year, to bolster the company's storytelling acumen, he hired an editor in chief, former Vice executive Ariel Wengroff. She oversaw a crypto education project called Ledger Academy and kicked off a podcast and video series. Some of the engineers at Ledger didn't understand why those nontechnical hires were necessary. Gauthier saw their resistance as part of Ledger's problem. "I was saying we could sell tens of millions of devices, have billions of revenue, billions of valuation. And they were like, 'Yeah, whatever.'"

But Rogers' most significant contribution might have been igniting the interest of his friend Fadell. Fadell had seen a weakness in Ledger's plan—the device itself was unlovable. To unlock the wallet, you had to enter a four- or eight-digit passcode using an incredibly awkward interface, like writing an essay on a home security panel. He began pondering what a better solution might be.

Fadell met with Gauthier at a Paris café, and they agreed that Ledger needed its next product to have broader appeal. They parted ways, but Fadell kept brainstorming. When he hit on a vision, he met with Gauthier again. "I want to be the chief designer on that," Fadell told him. Gauthier immediately agreed.

"I didn't believe in all that crypto hype, but I believe in the technology," Fadell says.



Ian Rogers, the chief experience officer and a former digital music executive, got curious about crypto and started collecting NFTs.

Ariel Wengroff joined Ledger to help spread the gospel of self-custody.

FADELL STARTED THE GIG FULL of ideas. As the guy who swept away the pain points of first-generation MP3 players (big and clunky, engineering degree required to select a song) and thermostats (ugly, no connectivity, impossible to program), Fadell was quick to understand the shortcomings of Ledger's wallet. Its screen was tiny, it lacked a keyboard or keypad, and its appearance and charm were on par with an early-2000s USB stick. The startup instructions warned users to set aside a minimum of 30 minutes.

In his mind, the wallet should be about the size of a credit card and have a touchscreen. The setup time should take no more than three minutes. You should be able to personalize the lock screen to display anything you want. He also envisioned people owning several wallets, one for each category of digital collecting or banking. He liked the concept of stacking them on top of each other, like a cash bundle of $100 bills. He came up with the idea of having magnets to snap the units into a tidy stack. That feature provided the name for the device: Stax.

Fadell surveyed all possible electronic components, talked to suppliers, and began prototyping, using green plastic toy blocks and magnets. One design constraint was battery life—Fadell wanted people to be able to leave their wallets untouched for months and still have power when they retrieved them. That meant the screen had to use energy-efficient E Ink. (Color would have been nice, but the tech isn't there yet.) Fadell took apart a bunch of Kindles and ReMarkable tablets to test how the screen might display a keyboard and other buttons.

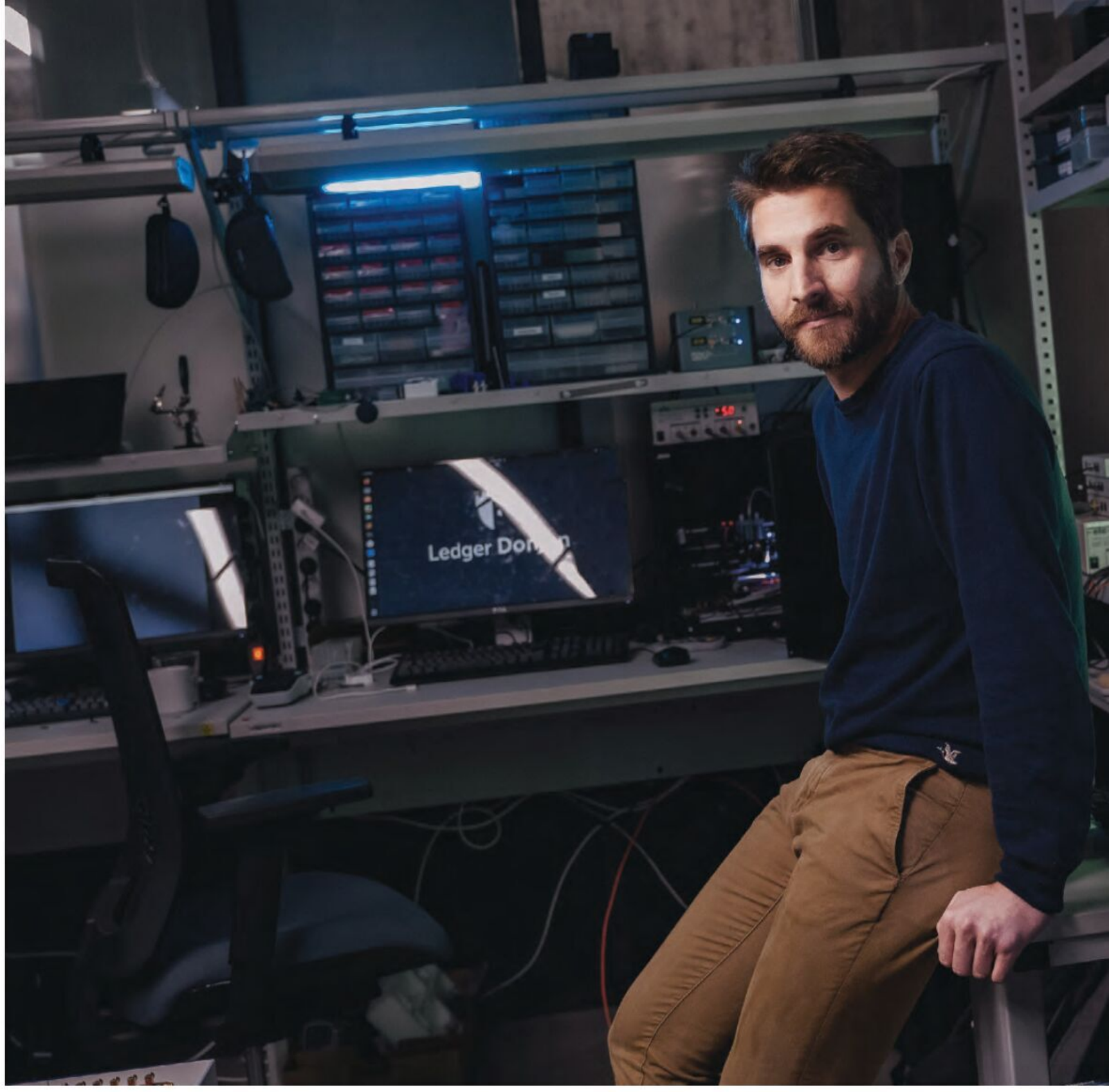
One of his dreams was to extend the screen along the edge of the unit, so people could label it. None of the E Ink displays he saw could do what he wanted, so he contacted an old friend, the UK venture capitalist Hermann Hauser, who had once been involved in an unsuccessful ebook device with advanced E Ink. That company, Plastic Logic, was now based in Dresden, Germany, and was making custom E Ink displays. And they could bend! The curved display had at that point been used only by an obscure Russian phone called the YotaPhone. Fadell wanted to produce hundreds of thousands of screens with a dramatically sharper curve and at a low cost.

Adding a touchscreen to the wallet presented a risk, though—a sophisticated attacker could, with the right equipment, pick up electronic signals leaking through the screen and figure out the pin code that unlocks the device. So Ledger's engineers had to shield the screen so it emitted no digital exhaust. They also wrote their own driver, the code that helps render pixels on the screen. "You're compromising security if you use a driver written by someone in China that you've never met," Rogers says.

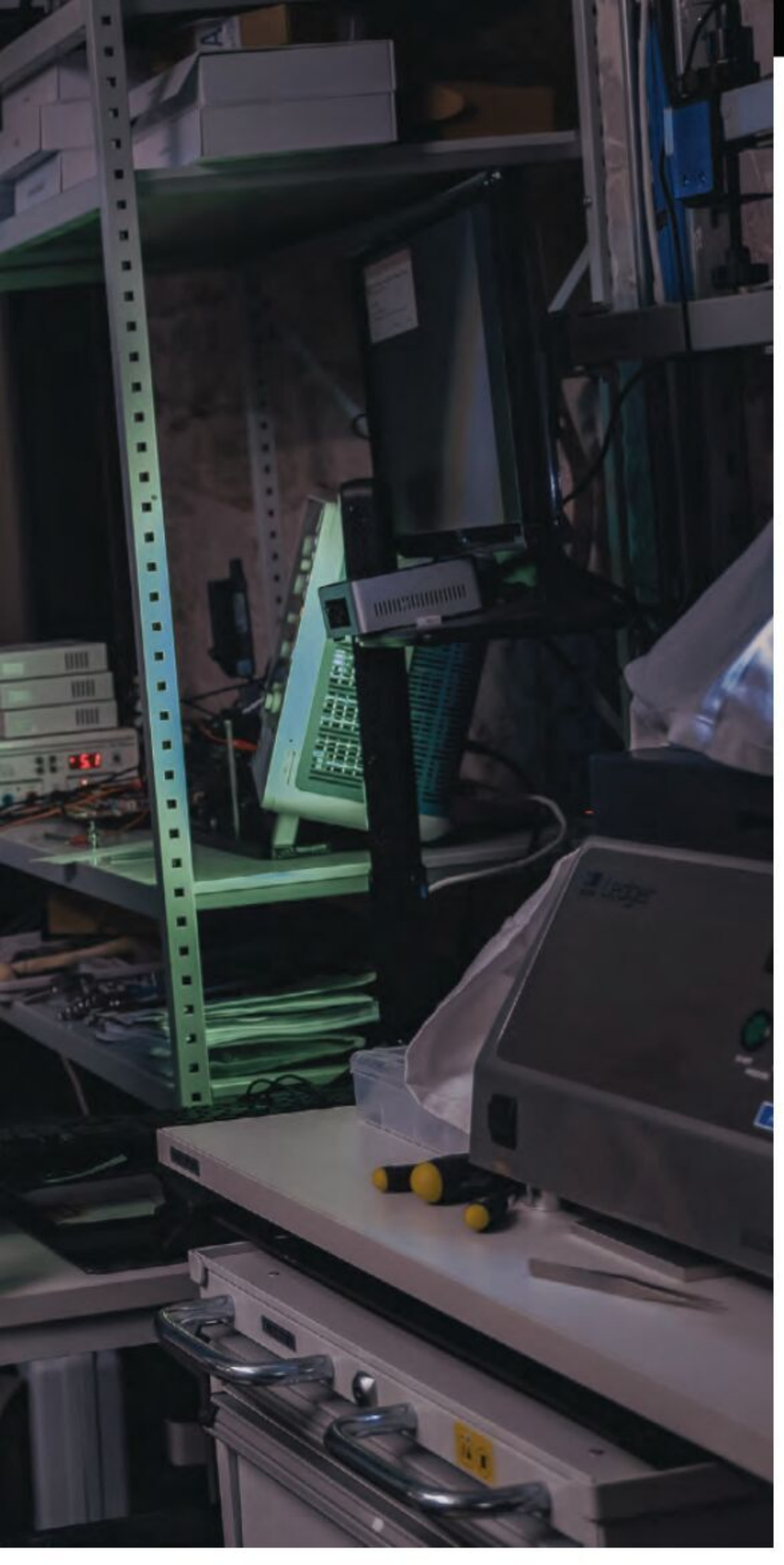
Meanwhile, Fadell was increasingly showing up at Ledger as the de facto lead of its new flagship product. (Though he never became an employee, Fadell says he was granted significant equity.) Not everyone welcomed him. Put magnets on a hardware wallet? Add a curved screen? From a supplier who'd never done that before? Plus, Fadell can be exacting to the point of infuriating. "I can't tell you how many times they'd say, 'Oh, this seems difficult—a rolled screen?'" Fadell says. "And I'm like, 'I'm telling you, we're going to do this thing. How many times do I have to say, just trust me, it's going to happen.'"

Early on, Gauthier had to convene his engineers and quell a possible rebellion. "They were saying all those things had never been done before. And I'm like, *Shut the fuck up*. If he says we're going to do it, we're going to do it." Apparently, they bought in: Some of those engineers described Fadell's style to me much the way he likes to be viewed—grueling, but inspiring. Like his former boss Steve Jobs. (Maybe if I spoke French I could have cornered them and gotten more candor.)

Ledger saw other benefits of having Fadell on board. Early in 2022, Foxconn,



Charles Guillemet, the CTO, told Fadell he was appalled at people who kept their private keys on a laptop or phone.



the manufacturer that Ledger retained to assemble the Stax units, said that it was going to miss its February 2023 deadline for shipping final products. Maybe June? "We were freaking out," Gauthier says. Fadell told him, "I got this." He wrote to Foxconn's CEO, explaining that the deadline was important and it would be a great favor if he looked into it. "Fifteen minutes later, boom, we were back on track," Gauthier says.

WHEN I ARRIVE IN PARIS IN OCTOber, the first prototypes are finished, and the team is working out the remaining bugs. Sitting with Fadell and Wengroff in Rogers' apartment in the Marais section—a fourth-floor walk-up accessible through an unmistakably Parisian courtyard—several units are neatly, um, stacked on the table, alongside a plate of fresh croissants. On the spine of one of them is the phrase BANKS ARE DEAD. I watch as Rogers buys an NFT. He does the actual selection and transaction on a phone. The Stax wakes up when it's time to verify Rogers' private key, alerting him that a pending transaction awaits his verification. Punching in his passcode on the display—sheltering with a cupped hand so I can't shoulder-surf—he buys it. Within a few minutes, he can view the image on his phone and edit it so it shows up in gray scale when he ships it to the lock screen of his Stax.

It may be a stretch to imagine a mass movement toward crypto coins and digital goods. Ledger's very long-term vision is that with secure, well-designed hardware as a bedrock, people will gravitate to crypto to verify their identity and credentials. Think driver's licenses, passports, proof that you passed your dentistry boards, Taylor Swift tickets, and voter ID. Rogers says that when he attended the NFT NYC conference in June 2022 and digitally verified he had the token required to register for exclusive events, an irony struck him. "The technology I use to get into parties is more secure, easier to use, and better than the technology that I use to get into our country! Fast-forward into the future and your government document is in your hardware wallet."

To advance this vision, Ledger has so far met only with consultants from Estonia, a nation known for embracing any futuristic scheme that comes its way. A cool wallet can only do so much; it's not going to win over people who struggle through 40,000-word crypto explainers in allegedly plain language and still can't figure it out. Does Ledger really think it can transform the industry?

"That's the hope," Fadell says. "To have that iPod moment for digital assets." He has concluded that a hardware wallet is inevitable: "You can't just integrate it into a phone, no matter how much you try. You need to have a real physical key in your life that holds the digital."

As we sit in Rogers' sunny Paris flat, it all seems plausible. Less than a month later, the blockchain world would blow up at the hands of a bogus crypto king in the Bahamas.

As we sit in Rogers' sunny Paris flat, it all seems plausible. Less than a month later, the blockchain world would blow up at the hands of a bogus crypto king in the Bahamas.



Stax wallets have wraparound touchscreen displays and magnets that let users snap together the little booklet-shaped gadgets.

IN EARLY NOVEMBER, GAUTHIER, Rogers, Fadell, and Wengroff visited New York City, and we met in a downtown bistro. As the espressos were being pulled, I asked about the fuzzy-haired, short-pants elephant in the room. Only a week earlier, a young crypto magnate named Sam Bankman-Fried had presided over the biggest disaster in crypto since Mt. Gox. "SBF" had allegedly redirected a chunk of customer deposits from his multi-billion-dollar crypto exchange FTX to cover the failing high-risk investments handled by a trading company he controlled. When customers went to withdraw their funds, some of them discovered they couldn't. His crew had annihilated at least a billion dollars' worth of wealth, stiffing more than a million customers and demolishing crypto's reputation.

The implosion capped off a convulsive year. The prices of cryptocurrencies have sunk, and NFTs have gone from galleries to Goodwill. Considering all this, launching Stax now could seem like introducing a new cocktail in the lounge of the *Titanic*, just as the ship smacked into the iceberg.

"Non, non!" insist the folks at Ledger. They say that FTX has been a *boon* for their company. It was a vindication of self-custody. People who had been holding their digital assets inside exchanges were now pulling out their funds and moving them to hardware wallets. The previous day, a Sunday, Ledger had set a sales record, and now it was on track to break it again.

As customers poured in—and existing users who hadn't fired up their wallets in months suddenly decided to update the firmware—Ledger's servers were temporarily swamped, and for an hour or so, customers couldn't update their software. Some got spooked. The company's support team sent out an ill-worded message assuring everyone, in a tweet, "Your assets are safe." Of course they were—that's what self-custody is all about. But after Bankman-Fried uttered those same words, the phrase became a signal that a house of cards was falling and your assets were *gone*.

If even savvy crypto folk get panicky at a hiccup like that, just imagine the reluctance of Web3 holdouts. Might it be unrealistic for Ledger to expect newbies to pay almost $300 for a wallet that has a fun picture on it but still depends on a somewhat impenetrable ecosystem and an existential question of reliability?

To the Ledger-ites, the promise of crypto and the necessity of self-custody will prevail. It's a logical outcome of the last half-century of atoms moving to bits. Still, Rogers admits that no matter how slick Stax is, it interacts with systems that have massive barriers to entry.

After breakfasting at the bistro, I spent an hour with him trying to get set up to trade crypto and buy NFTs. While getting the wallet to authenticate me was easy, getting the currency needed to buy the funky artworks Rogers likes proved frustratingly difficult, and apparently impossible to complete in the time we had. "Crypto is where the internet was in 1993," he finally said, in a tone somewhere between wistful and pissed off. That doesn't bother him too much—the iPod, after all, came out in the early, awkward days of digital music and took a few years to catch on. "The only question in my brain is, are we the Apple of Web3?" Rogers says. "Or are we the BlackBerry or Nokia of Web3?"

We've already seen the FTX of Web3, so there's nowhere to go but up. For now, Tony Fadell's latest technology tour de force stands as a friendly hardware ambassador for a future that's still far away for most of us, and a glimpse of how we might wind up with something useful, accessible, and enriching—from what so far has been a blockchain of fools.

STEVEN LEVY *(@stevenlevy) is* WIRED*'s editor at large. He wrote about Meta's Oversight Board in US issue 30.12/31.01.*



Earth is teeming with unknown species, and they're dying off faster than ever.

Now biologists are in an urgent battle over an old question:

How should humanity catalog life?

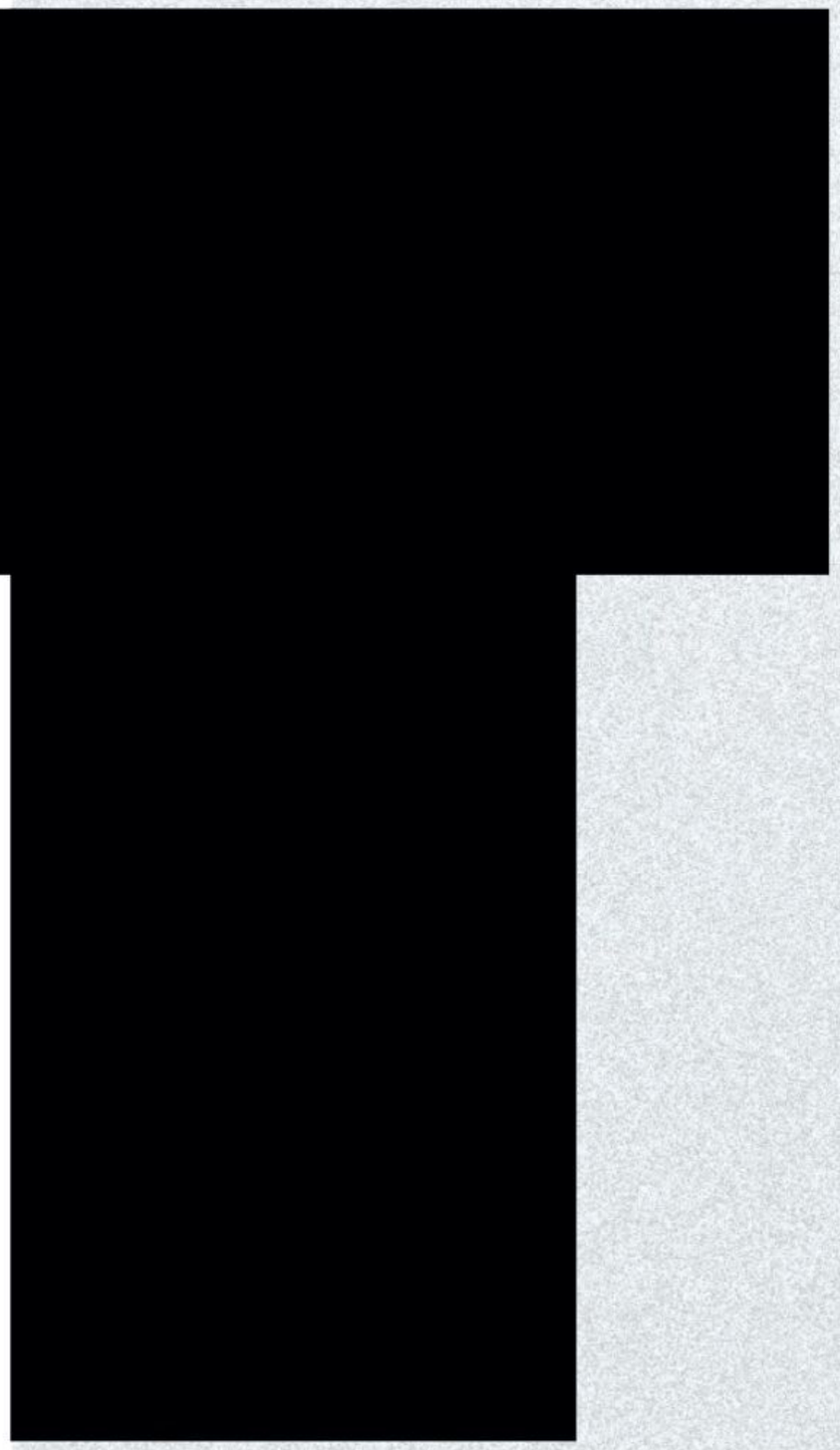
photographs by
Damien Maloney

THE BIG FIGHT

OVER 403 VERY SMALL WASPS

by BROOKE JARVIS

(1 .)



THE BOTTLE HELD A THIN BROTH, LIGHT BROWN, WITH SOME uncertain chunks of dark matter bobbing on top—a soup, maybe, but one that you'd never want to eat. Once it was poured into a white plastic tray, the chunks resolved into insects. Here were butterflies and moths, the delicate patterns of their wings dimmed after a week or two in ethanol. Here were beetles and bumblebees and lots of burly-looking flies, all heaped together, plus a bevy of large wasps, their stripes and stingers still bright.

Michael Sharkey took out a pair of thin forceps and began examining his catch. It included anything small and winged that lived in the meadows and forests around his house, high in the Colorado Rockies, and that had suffered the misfortune, in the previous two weeks, of flying into the tent-shaped malaise trap he had erected in front of his home and we had emptied earlier that morning.

Though Sharkey is a hymenopterist, an expert on the insect order that includes wasps, he ignored the obvious stripes and stingers. He ignored, in fact, all of the creatures the average person might recognize as wasps—or even recognize at all. Instead, he began pulling little brown specks out of the soup, peering at them through a pair of specialized glasses with a magnifying loupe of the sort a jeweler might wear. Dried off and placed under the microscope on his desk, the first speck revealed itself to be an entire, perfect insect with long, jointed antennae and delicately filigreed wings. This was a braconid wasp, part of a family of creatures that Sharkey has been studying for decades. Entomologists believe that there are tens of thousands of species of braconid sharing this planet, having all sorts of important impacts on the environments around them. But most humans have probably never heard of them, much less been aware of seeing one. Huge parts of the braconid family tree are, as the saying goes, still unknown to science.

As a taxonomist, Sharkey is part of a small group of people who can transform anonymous insects into known species. When other entomologists find specimens they think may not yet have been named, taxonomists are the specialists they call in to investigate whether this seemingly new-to-us thing is actually new to us. If it is, the taxonomist may formally welcome it into the realm of human knowledge by publicly conferring upon the species a Latin name, along with an official description of the physical characteristics that make it unique and identifiable for future observers. The process "hasn't changed an awful lot" in the past 200 years, the British hymenopterist Gavin Broad told me—except that nowadays "we've got nicer pictures."

I first encountered Sharkey's name months before I called him up and asked if we could look at bugs together. I don't remember precisely when, only that I gradually started to notice the name—always followed by "et al."—in more and more places. There were long critiques of Sharkey et al. appearing in scientific journals, and then, later, there were responses to those critiques, and



➜

Michael Sharkey has named hundreds of species of braconid, some of which are as small as 1 millimeter long.



The initial paper wasn't written to be PROVOCATIVE, Sharkey said. "But provoke it did."



responses to those responses. And then there was the snark among the entomologists in my Twitter feed, some of whom called the work irresponsible or embarrassing or just wrote "Wooooooof."

"Sharkey et al." is shorthand for a paper that came out in the journal *ZooKeys* in 2021, along with a series of subsequent publications that used similar methods. That first paper wasn't the sort of work that usually raises such a hubbub. In it, Sharkey and a group of coauthors named some new species of braconid wasp that had been caught in malaise traps in Costa Rica. But instead of identifying just a few species, they named 403. And instead of writing up detailed descriptions for each new wasp, the authors simply included a photo and a snippet of genetic code.

The technique that Sharkey and his coauthors used, called DNA barcoding, is a way of quickly sorting and differentiating species. Researchers analyze a small section of DNA at a particular site in each creature's genome, upload that sequence into a vast database, and then use algorithms to sort the different sequences into groups. When the DNA varies from one organism to the next by more than a few percent, it's considered a sign that their evolutionary histories have gone down separate tracks for a significant period of time, possibly dividing them into different species.

DNA barcoding is a common scientific tool these days. But some scientists said that Sharkey and his colleagues had pushed its use too far. They deemed the work "turbo taxonomy" or even, as the taxonomist Miles Zhang said, "taxonomic vandalism," a term for labeling taxa as new without sufficient evidence for their uniqueness. These critics argued that the work could undermine the whole project of naming the natural world, of beginning to make it legible to human understanding. Zhang—who is actually Sharkey's academic "grandson," having studied under one of Sharkey's former students—was so frustrated that *ZooKeys* continued to publish papers from Sharkey et al. that he tweeted to the journal, "I'm done with you, go find a new subject editor."

For Sharkey and other entomologists who support his approach, this method of accelerated taxonomy is an urgently needed response to ecological calamity. Here we humans are, on a planet of astounding diversity in which truly enormous numbers of our neighbors are still mysteries to us—are, in fact, slowly revealing themselves to be more mysterious than we ever realized—and at the same time we're pushing those other species rapidly toward oblivion. What choice is there, Sharkey asked, but to do all we can to speed up the naming process, if we are to learn what we're losing before it's gone?

The initial *ZooKeys* paper, Sharkey insisted, was just a start, a suggestion for how taxonomists can begin to tackle the enormous challenge that faces them. It wasn't written to be provocative, he said. "But provoke it did."

The more I learned about the debate, the more captivating I found it. In one sense, it was an esoteric argument about technical methods within a pretty obscure field—one that's often written off, as Zhang put it, as "a weird hybrid between true science and stamp collecting." But there was clearly a lot more at stake than a few hundred wasps. Taxonomy, for centuries, has been humanity's way of reckoning with the great unknownness of the natural world. It's how we have gotten acquainted with our neighbors, how we have tried to understand our place in a wildness whose true scope and complexity have always eluded our grasp. As the biodiversity crisis that our species created pushes others toward extinction, the field is struggling in ways that reveal just how much we have to lose.

(2 .)

THE NAMING AND ORDERING OF living creatures is one of the most enduring human preoccupations. We're taught to do it as children, and it's one of the first jobs God assigns Adam in Eden: Give a name to every beast of the field and bird of the air. Aristotle's classification of living things into ranked groups created a foundation for the regrettably world-changing belief that nature exists in a fixed hierarchy, with humans on top and the rest below, separate and endlessly exploitable. We saw chaos and nominated ourselves to create order.

Modern taxonomy began with Carl Linnaeus, an 18th-century Swedish botanist, who, at the age of 28, published *Systema Naturae*, a bold claim that he could organize all things animal and vegetal into a system of neat and nested hierarchies: kingdom, phylum, class, order, family, genus, species. (He also ranked groups of humans, a theory that laid the groundwork for using science to justify racism.) By the time Linnaeus died, his system included 12,000 organisms. Since then, the naming and ordering of creatures has been a vast collective project, undertaken by generations of scientists and laypeople. Named species, as Zhang put it, have become "the basic unit of biology," a fixed point around which all sorts of laws and conservation strategies, not to mention centuries of scientific literature, pivot. Linnaeus' 12,000 named species grew to today's far more impressive (and very approximate) 2 million. But even that number, any biologist will tell you, is just a very humble start.

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Sharkey uses ethanol to preserve the specimens caught in his traps.

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One problem is that scientists can't fully agree on a single way of defining what a species *is*. The field of taxonomy was born when humans believed organisms to be fixed and immutable, but it must now operate in a world that we understand to be defined by mutation, variation, and constant change. (Even the author of *On the Origin of Species* once wrote to a friend how maddening it was trying to draw hard boundaries around organisms. "I have gnashed my teeth, cursed species, and asked what sin I had committed to be so punished," Darwin wrote.) One common definition says that two organisms are different species if they can't interbreed—which makes good sense until you think about, say, the climate-change-induced merging of polar bear territory with grizzly territory, resulting in pizzly bears. Or the fact that the bears share ancestry; at what point was the divergence enough to make them different species? The history of taxonomy includes a long series of battles—driven by evidence, opinion, and personal predilection—over whether groups of specimens ought to be lumped together or split apart.

But the problem of species is bigger still. Hundreds of years into the Linnaean project, scientists estimate that they have named, oh, somewhere between a fifth and a thousandth of the species on the planet. The general public tends to believe that the discovery of a new one is a momentous and rare occasion. In fact, the backlog of unclassified specimens is enormous. With most insects, especially, there is simply no keeping up. A Dutch entomologist told me about opening a large drawer full of various unnamed beetles at a museum, only to be told that the forest where they'd been collected a century earlier had long since vanished, the beetles probably gone along with it. Entomologists often say they could probably find a new-to-science species of insect in just about any given backyard, if only you gave them the time and access to experts. I'd heard this time and again, but I still wasn't quite prepared when Sharkey examined one of the specimens from the backyard braconid soup and remarked, mildly, that he thought it was likely new to science.

Braconids are a perfect example of the staggering unknownness of the natural world. They're part of a larger group known as parasitoid wasps, which reproduce by hijacking the life cycles of other insects. The wasps lay eggs in or on hosts such as caterpillars, ants, or beetles. Their larvae then use the hosts as food, often eating them from the inside out. In some cases, thanks to neurotoxins imparted by the parent wasp, the host is still alive—a grotesque but efficient defense against food spoilage!—during the ordeal. (The whole situation was enough to put Darwin off his society's prevailing religion. "I cannot persuade myself," he wrote to a friend, "that a beneficent and omnipotent God would have designedly created" such creatures as parasitoid wasps.)

Still, parasitoidism provides a pretty thrilling window into the richness of evolution. It's thought to lead to incredible specialization, and therefore incredible diversity. Parasitoid wasps often evolve intricate ways of infiltrating the defenses of a single other species of insect, or perhaps a few—at which point the host species evolve new defenses, and the parasitoids new strategies, ad infinitum. Take the braconid wasp that parasitizes the green cloverworm, a caterpillar. The prospective host tries to escape its waspy enemies by dangling itself off branches by a safety thread, like a little bungee jumper. The braconid has evolved to subvert this strategy and slide down the thread in pursuit of the caterpillar. But that's hardly the end of things, because there's *another* parasitoid wasp, a whole other species, that lays its eggs in the first braconid's eggs and has specialized to look for them by reeling the green cloverworm caterpillar back up. (It will lay its own eggs inside only if the first braconid has already deposited its young.) Sometimes these chains of bespoke predation, known as hyper-parasitism, go on for layer after layer, a Russian nesting doll of endlessly multiplying diversity and coevolution.

For a long time, scientists believed that the most speciose group of insects—and therefore of animals on Earth, since the vast majority of the world's animal species are insects—were beetles. Some 400,000 species have been named, so many that the famous polymath J. B. S. Haldane, when asked by a cleric what a lifetime of studying the natural world had taught him about the God who had created it, is said to have replied, dryly, that any such divine being must have "an inordinate fondness for beetles." But recently, some entomologists have argued that, thanks to the enormous variety beginning to emerge as we learn more about parasitoids, it's actually *wasps* that are likely to be the world's most inordinate group. They may attract less human attention than iridescent jewel beetles, but these overlooked creatures, with their disconcerting reproductive strategies, so deeply embedded in the lives of the species that surround them, may represent a dominant way of animal life on planet Earth. As Broad, the British hymenopterist, said, "What do you know about the world if you're only looking at a few species? You don't know anything about it."

In recent years, as entomologists around the world have tried to quantify the alarming arthropod decline that's widely known as "the insect apocalypse," they've had to contend with this "Linnaean shortfall"—the fact that humans have so little preexisting knowledge of the other organisms with which we share our planet, much less how they're faring in the face of unprecedented global change. (There's also, if you want to get nerdy about it, the "Prestonian shortfall," which refers to the shortage of baseline data about how abundant animals really were in the past, and the "Wallacean shortfall," or all that we don't know about how species have moved in space, and the "Darwinian shortfall," what we don't understand about the way species have changed over time.) And there is the taxonomic shortfall: the knowledge we're missing out on because there aren't enough people or resources to help us meet the neighbors before they vanish.

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LIKE A LOT OF FUTURE NATURAL SCIENTISTS, SHARKEY GREW up—in his case, outside of Toronto—as the kind of kid who loved collecting bugs and salamanders in jars. Later, his work as a taxonomist sent him on professional collecting trips, chasing insects to the far reaches of Canada or Colombia. Just as often, though, it took him to arguably more obscure places: dusty monographs, old books, and the filing cabinets of distant museums. (As in many fields, taxonomy is shadowed by a persistent colonialism; specimens regularly end up half a world away from the forests or fields in which new scientists might be examining their living descendants.)

In biology, the scientific name of an organism is formally attached to a particular specimen, what's known as a holotype. Should you have questions, for example, about what sort of bear chased you through the wilderness, you may wish to visit the preserved head of Mammal #100181 in the American Museum of Natural History, the official holotype of *Ursus arctos alascensis*, the Alaska brown bear. (Museums also hold paratypes, specimens of the same species collected alongside the holotype, which are equally handy for validation, though vested with less symbolic meaning.) Type specimens are particularly valuable to insect taxonomists, who often compare very subtle differences—the details of a moth's antennae or a beetle's spiny genitalia, for example—to tell species apart or find out if they've already been named.

In the years when Sharkey was working on his PhD, a project to name and describe 100 species of braconid, he visited some 10 museums across North America and Europe just to examine long-dead wasps. In Berlin, in the 1980s, he passed through a checkpoint from West to East day after day on his way to inspect some key specimens. The guards would raise their eyebrows at his microscope in its big cylindrical metal case but then let him through. In the end, investigating, naming, and describing those 100 species took seven years.

The work was slow and tedious, and there were always doubters who questioned the point of it all: first Sharkey's father, who insisted that the pure sciences were frivolous and that his son should go into medicine or law, and later the head of Sharkey's undergraduate entomology department, whose face fell when he discovered that his student was interested in studies on ecology and evolution, not agriculture and economics. But Sharkey relished the job. He loved how it felt to find patterns within chaos, teasing out and learning to recognize the subtle physical differences that distinguished one genus or species from another. He loved being able to walk through a forest or grassland and identify the key players in tiny dramas, to observe the complex ways in which insects' lives interacted with each other. And then there was that feeling of discovery, the thrill of the new, of doing his part to expand the world of human awareness, however slightly. Naming a new species, he thought, felt a little like summiting a mountain or discovering the wreck of a Spanish galleon. Even if it was a tiny wasp.

But that was then. As genetic technology became cheaper and more accessible, Sharkey decided to revisit his old work to see how the distinctions he'd made based on an animal's morphology—those subtle physical details—compared to the differences evident in its DNA.

The results shocked him. The work hadn't just been slow; much of it seemed to be wrong. According to the genetics, some of the animals he'd diagnosed as one species were best understood as four or five; others, which he'd named as multiple species, were only one. It seemed that as much as half of his work was, at best, misleading. "The morphological work I was doing was just garbage," Sharkey said. "I thought, my God! I've wasted 20 years of my life, or at least my professional life."

The DNA barcoding technique that Sharkey used was pioneered by the Canadian biologist Paul Hebert, who proposed the idea in 2003 after looking at barcodes in a grocery store. How could we track so many flavors of Pop-Tarts and pasta sauces, he wondered, but not the living things with which we share the planet? Hebert later founded a major institution, the Centre for Biodiversity Genomics at the University of Guelph, which has championed the technique and built a database of genetic barcodes and the organisms they key to, in order to help speed identification. This system algorithmically lumps together sequences whose genetic relationships are particularly close. These sequences are assigned the same barcode index number, or BIN.

Often, the DNA reveals only more secrets: Ecosystems are full of mystery creatures whose genetic data is not yet associated with any name at all.





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Five braconids of the genus *Retusigaster*. They parasitize caterpillars.

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Sharkey examines dried and pinned braconids from his collection.

Since Hebert developed the technique, the use of DNA barcoding has expanded in dramatic and creative ways. You can, for example, test the DNA present in snow or river water or soil, or even in the stomachs or excrement of animals, and thereby "see" the many organisms that have passed invisibly through the landscape or digestive tract. Often, though, the DNA reveals only more secrets: These ecosystems can be full of mystery creatures whose genetic data is not yet associated with any name at all. Not all are necessarily "new" to science; in some cases they may have been named and filed away in a museum but never really studied again, and the link between their name and their DNA has not been made. The taxonomist Roderic Page once dubbed these unnamed species "dark taxa." Some other scientists soon adopted the term to refer to a bigger darkness—the enormous category of all undefined life. As with dark matter or dark energy, here is a force that humans generally don't see or understand but that has a profound effect on how our natural cosmos works.

When the taxonomist Rudolf Meier and a group of coauthors analyzed more than 200,000 insects caught in malaise traps in eight countries, in habitats ranging from tropical rain forests to temperate meadows, they found that the insect families that dominate the natural world—the hyperdiverse ones full of species whose interactions (such as pollination or predation or decomposition) with other organisms play key roles in ecosystems—are also the families that are among the least known. Meier called this "the neglect index." The same phenomenon, he told me, extends to lots of other key groups, from microbes to fungi to ringed worms, that quietly help keep the world running despite not having much in the way of names. "From a biomass point of view, from a species diversity point of view, a lot of the taxa that have received most of our attention are not important," he said. "But all the taxa that we have been neglecting *are* important."

The other big surprise of barcoding was how often it revealed that even the knowledge we thought we had was, in fact, incomplete or flawed. Sharkey's experience of watching the genetics contradict his morphological analysis is becoming a common one. In the past 15 years, scientists have split what they thought was a single giraffe species into four, the orca whale into at least three, the well-known and long-studied *Astraptes fulgerator* butterfly into 10. Often, a discovery of genetic difference kicked off a closer look at animals' survival and reproductive strategies, at their morphology and how they interacted with their ecosystems, which in turn revealed meaningful differences that had gone unnoticed or unappreciated. I talked to Guilherme Oliveira, a researcher in Brazil, who barcoded an Amazonian ecosystem and found hundreds more plant species than anyone had expected—a profusion of biodiversity that scientists had previously failed to see.

Parasitoid wasp species are proving equally full of hidden diversity. Where entomologists once saw one or two generalist species—organisms capable of parasitizing a variety of different hosts—DNA barcoding will sometimes reveal a dozen specialists, which are much more narrowly adapted. This is not just reclassification for its own sake. Specialists are particularly vulnerable to extinction, and the particulars of who eats whom can matter a great deal in ecosystems—including those that humans depend on most. On farms, when introduced pests, freed from the constraints of their natural predators, destroy vital crops, suddenly it's a race to identify the right parasitoid defender to stave off failure or famine. The wasps are air-dropped like tiny paratroopers into crisis zones.

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IN HIS OFFICE IN COLORADO, Sharkey showed me old monographs and morphological keys meant to guide people in identifying various parasitoid wasps. He lamented how "useless" they were. Some of the written descriptions seemed like they wouldn't be much easier to follow than a genetic code; many specimens didn't key out to a species, or keyed out to the wrong one, because the keys included only the small subset of species that had been discovered at the time and no information on the much wider world that really existed.

When he first learned that his morphological work had been so mistaken, Sharkey told me, he felt depressed and demoralized. But then he became an evangelist. The slower road, he said, continued to make more sense for well-studied groups associated with long scientific literatures. But a hugely speciose and mostly unknown group like the braconids, he insisted, was different. What was the point in making morphological keys if they didn't work very well and hardly anyone looked at them? The sheer scope of the unknown demanded triage. Better to barcode quickly now and do the in-depth descriptions later, if there was ever time.

The approach made sense to some scientists. There are groups that are so large and so cryptic, and in so much danger from the ongoing collapse in biodiversity, that it's "not logistically feasible to do the taxonomy the old way," Scott Miller, the curator of *Lepidoptera* for the National Museum of Natural History, told me. "In order to meet the challenges at hand, we have to move faster." Dan Janzen, the

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The microscope in Sharkey's home office with a pinned braconid on the stage.

The goal shouldn't be to file other organisms into our own human systems, one scientist said, but to try to "think of it from the way they think about themselves."





renowned entomologist who provided the Costa Rican braconids in the original *ZooKeys* paper (on which he and his wife, the tropical ecologist Winnie Hallwachs, are coauthors), believes that as barcoding becomes cheaper and more accessible, it will help democratize the process of gathering information about the world's biodiversity—and encourage more people to have a stake in protecting it. This is the power of naming, he said. Names help us relate to a species, see it, notice it, care about it. "*Bioalfabetización*," he calls the process in Spanish: the development of biological literacy.

But others warn that taxonomy can't afford to sacrifice precision for speed, and that it needs to respond to technological advances by incorporating more types of information, not fewer. Some of the arguments are about accessibility: How can the field become more democratic if you need access to a sequencing lab to identify a bug in your own backyard? Other objections are technical. The mitochondrial gene that's usually used in barcoding, called cytochrome oxidase I, or CO1, is not necessarily the best option for analyzing the genetic differences between species, especially as technology has expanded to allow for cheaper analysis of a fuller genetic picture. CO1 isn't directly related to reproduction, and it doesn't work well for all groups of animals. (Fungi, for example, or oak gall wasps, which Zhang studies—if you look just at CO1, he says, you miss the entire diversity of this megadiverse group.)

Meier agrees that taxonomy needs to be sped up dramatically if it is to take on the great unknowns of the natural world, let alone keep up with the speed at which nature is being destroyed. But he believes the future lies in integrating barcoding with a variety of other advanced technologies, including robotics and machine learning, which can perform rapid analysis of images and discern species based on subtle differences that humans struggle to see.

Meier and Sharkey have gone back and forth in journal articles over whether Sharkey's method unfairly equates BINs, which are changeable categories whose boundaries can shift as new data is added, with species, which are meant to be stable reflections of separate evolutionary histories (despite being muddled by differences across geographic ranges, niches, and populations). When Meier performed his own analysis, which ran some of the same data through different algorithms, it sorted the wasps into a slightly different configuration of species than the algorithm Sharkey had used. The technology had improved, but a version of the old lumping–splitting debate was still there. The boundaries between species still shifted depending on who, or what, was drawing them.

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An insect trap in Sharkey's front yard.

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The mountains surrounding Sharkey's current home in Forest Falls, California.



The act of taxonomizing species captures humans at our most confident: Here we are, making grand pronouncements about what other creatures are, about *who* they are, naming them just like Adam before the Fall. Yet our desire to name nature has always run up against the grand abundance and wild complexity of the world we actually live in. In one telling, the story of our quest to understand the biodiversity around us is one of ever-expanding knowledge. In another, it's a tale of ever-expanding ignorance, of learning just how much we don't yet understand. While both morphology and genetics can tell us a lot about how other creatures survive on Earth, there will always be parts of other organisms' lives that matter very much to them but are hidden from us. Many insects, for example, can see spectra of light that we can't, and so look quite different to each other than they do to us. Plants use complicated chemical signals to communicate with each other, as well as with their predators and benefactors. Many animals, from birds to frogs to Belding's ground squirrels, differentiate themselves by smells or calls more than by looks, and scientists are increasingly turning to these differences to try to tell them apart. The goal shouldn't be to file other organisms into our own human systems, Miller said, but to try to "look closely at these organisms and think of it from the way they think about themselves."

This means trying to recognize, and minimize, the extent to which we're limited by our own biases, which include our tendency to privilege the visual over the olfactory or aural, the diurnal over the nocturnal, the big over the little, and animals with relatable faces over those without. The scientist Robert May, who helped pioneer the field of theoretical ecology, has characterized our ignorance of species without features and lives "akin to our own" as "a remarkable testament to humanity's narcissism." In *Naming Nature*, a book about the history of taxonomy, the science journalist Carol Kaesuk Yoon takes a more generous view: "There is nothing harder to see," she writes, "than one's own frame of reference."

Even as they argued with each other, the taxonomists I spoke to each described their work as an exercise in humility, of trying their best before a daunting unknown, and learning, over and over, how much they don't know. It can be a painful job, as a group of them wrote, "documenting this monumental historical loss of biodiversity and, in some cases, grimly identifying and naming new species already extinct or destined thusly." Even the fiercest arguments about methods and goals boil down to this: We live in a world of diversity that exceeds the grasp of our knowledge, but not our ability to destroy it.

Before I left Colorado, Sharkey opened a new box of vials that had recently arrived via the barcoding lab in Canada: more braconid wasps, this time from a large, and largely unknown, subfamily called *Doryctinae*. They had also been collected in Costa Rica and were now waiting to be named, in a new paper that would use a minimalist method similar to the one that had caused so much furor.

Sharkey poured the first one out of its vial, and it splashed onto a sheet of paper, tiny and anonymous. And then he put the wasp under the microscope.



FOR YOUR EYES ONLY

"One of the great things about being a photographer on assignment for WIRED is being granted access to places the public doesn't normally get to see," says Benedict Redgrove, who photographs a rocket factory in Scotland. "Of course, while I get to see lots of amazing things, inevitably, there's even more secret stuff that can't be shown. Skyrora is an ingenious company utilizing the latest technology in really clever ways. There's always so much more I would like to show when working on these stories, but hopefully what we were able to photograph tells the story."

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Colophon



THE SCIENCE OF COOL

"The lighting and composition were intended to convey a cool, science-y feel," says Laurence McMahon of his subject, cognitive scientist Abeba Birhane. "We shot in a lecture hall, but the simple background makes Abeba the story."

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A handmade 100% organic line of candles to help people create this atmosphere through scent where they can create their own inspiring ritual to balance their energy, practice aromatherapy and self-care. Use wrd25 for 25% off (expires 30/04/23). Visit **kndlzshop.com** and follow on IG: **@shyckndlz**

TYPE B COLLECTION



Launched in 2020, Type B collection was founded on the principle of quality while offering exceptionally creative designs. Montreal-designed and Italian-made, Type B demonstrates the versatility of scarves. Designed to tell a story, each scarf is fabricated using hand-made materials and meticulous attention to detail. Visit **typebcollection.com** and follow **@typebcollection** on IG.



STEPHANIE DILLON

STEPHANIE DILLON is a Minneapolis based artist who uses salvaged and reclaimed canvases as a base for her vibrant and colourful works. Stephanie has developed a bold style while utilising many mediums: from found objects and traditional painting to digital and crypto art, she uses these tools to express her pain, joy, and grief while highlighting her profound gratitude for life. She celebrates beauty in the unexpected and helping bring that joy to others through her work and through collaborating with other artists. Her feeling is that whenever something is thrown out, she can potentially turn it into something beautiful again. Art is everywhere. Pictured is "Paper Flowers on Broken Heart", an acrylic and aerosol painting on canvas with collaged vintage elements. For more information on Stephanie and her collaborations, visit **StephanieDillonArt.com** or follow **@stephaniedillonart** on IG.



MAEV

MAEV is one of the first US based human-grade raw dog food companies. Diet is the most important choice you make for a dog. Now, the healthiest choice is easy with Maev. Follow **@meetmaev** on IG or shop online at **meetmaev.com**

CARMEN DELPRAT

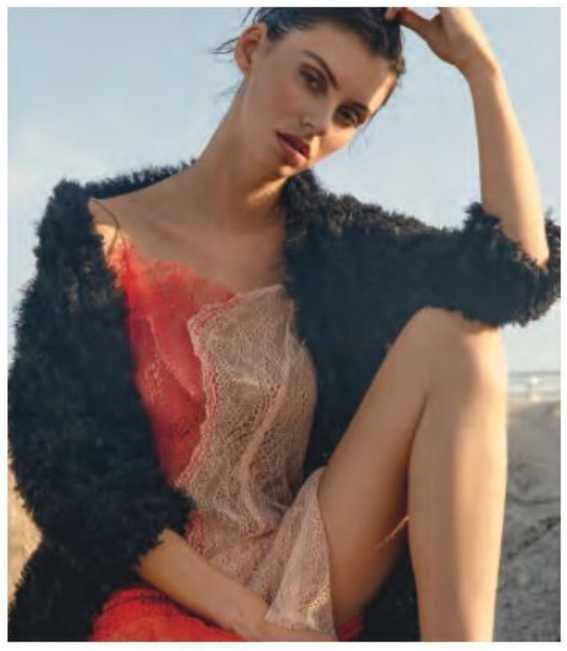


Carmen Delprat's exotic art merges in several styles including fine art, surrealism and symbolism creating dreamy interpretations of the world around her. Carmen sells her unique art as originals, fine art prints, gift cards and stunning art scarves, paring art with luxury in perfect harmony and style. Visit **www.carmendelpratart.com** and follow **@carmendelpratart** on IG.

WIRED ADVERTISING FEATURE

OTKUTYR

OTKUTYR Fashion House is known for its eco friendly techniques such as up-cycling, and reusing fabrics from older collections and pieces. OTKUTYR is dedicated to showcasing local artists and designers internationally by offering services such as creative direction and local production, amongst others. Follow on IG **@otkutyrfashionhouse** and visit **otkutyr.com**



MOI MILI



Moi Mili is a premium lifestyle brand, offering top quality lines of teepee tents for kids with floor mats as well as distinctive luxury pillows, decorations and accessories, crafted with genuine concern for the right mood at home. Visit **moimili.com** and follow on IG: **@moi_mili**

THE ASSIGNMENT: IN SIX WORDS, WRITE A STORY ABOUT LIVING FOREVER.

"SOMETHING NEW FOR DINNER?" SHE LAUGHED.

—J C Thrush, via email



Honorable Mentions

It wasn't long enough for me.
—@Anna_Wenner, via Twitter

And so long lived the Queen.
—Giacomo, via email

Too bad I never stopped growing.
—Antti Karjalainen, via Facebook

There was still no edit button.
—@ThatKP3, via Twitter

In the end, there wasn't one.
—Jason Anderson, via email

I woke up again and again.
—@mirnanassar, via Instagram

They said someday, but it's today.
—@VijayLRoy, via Twitter

I should've had that looked at.
—J. Fredrick James, via email

Want to submit a six-word story for us to consider? At the beginning of each month, we ask for new ideas on Facebook, Twitter, Instagram, and WIRED.com/six-word, where you can also see how we've illustrated past favorites.

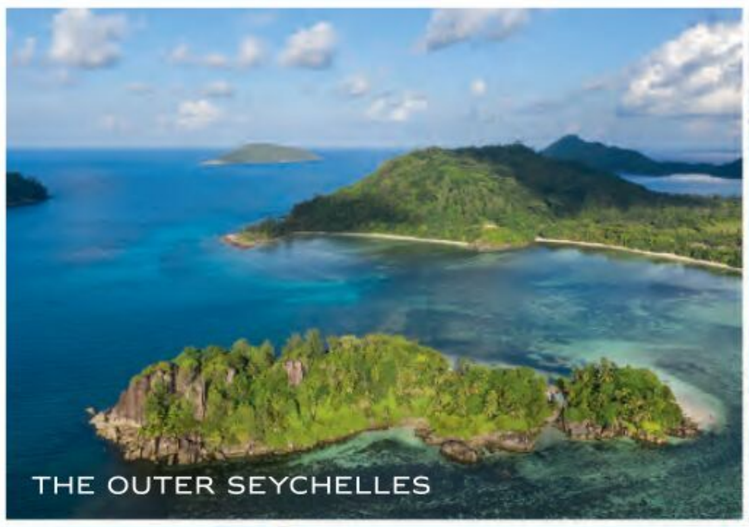
Disclaimer: All #WIREDSIXWORD submissions become the property of WIRED. Submissions will not be acknowledged or returned. Submissions and any other materials, including your name or social media handle, may be published, illustrated, edited, or otherwise used in any medium. Submissions must be original and not violate the rights of any other person or entity.

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THE OUTER SEYCHELLES


AZORES ARCHIPELAGO, PORTUGAL


FLORIDA GULF COASTLINE, UNITED STATES


SYLVIA EARLE EXPLORES
COCOS ISLAND, COSTA RICA


THERE ARE OVER 130
HOPE SPOTS GLOBALLY


SYLVIA EARLE WITH VOLUNTEERS,
THE OUTER SEYCHELLES


GREAT BARRIER REEF, AUSTRALIA

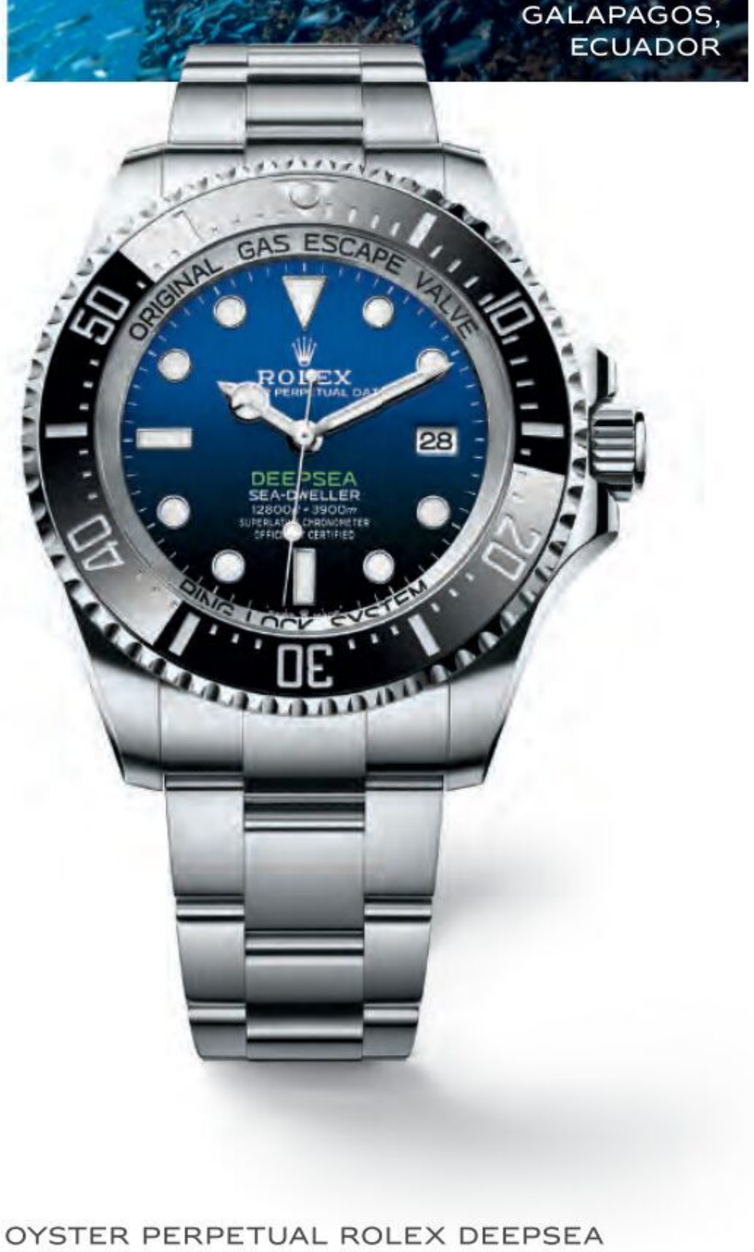

MOBULA RAYS, AZORES
ARCHIPELAGO, PORTUGAL


SEA LION,
GALAPAGOS,
ECUADOR

ON OUR WATCH

Hope can now be spotted across all our planet's seas and oceans. Sites are made into aquatic havens by local communities, to safeguard the richness and diversity of the ecosystems they depend on. Sylvia Earle's invaluable experience as an explorer and marine biologist continues to help further their goal, through her organisation, Mission Blue. Together, they have created over 130 Hope Spots and counting. Carrying a message of hope for generations to come. It is that vision, that dedication to a perpetual planet, which we are proud to stand by. **For as long as it is needed.**

#Perpetual



OYSTER PERPETUAL ROLEX DEEPSEA

MISSION BLUE

ROLEX SUPPORTS MISSION BLUE
IN ITS COMMITMENT TO PROTECTING
30% OF THE OCEANS BY 2030

ROLEX